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Writing, painting and sketching at Dunhuang: assessing the materiality and function of early Tibetan manuscripts and ritual items

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ABSTRACT

The paintings and manuscripts discovered in the sealed 'library cave' in Dunhuang, Western China, contain the earliest surviving examples of Tibetan artistic and scribal practice (9th–10th centuries AD). Despite their importance, their material characteristics have not previously been studied. The present paper discusses the results of the analysis of paper and pigments in a selection of items across a variety of forms and functions: (i) Buddhist manuscripts, (ii) official letters, (iii) hung paintings, (iv) ritual items, (v) banners, and (vi) stencils and preliminary sketches. The material analysis of these items is presented in historical context, to address three research questions. First, whether there is a correspondence between the materials used in the creation of these objects and their geographical origin. Second, in terms of the choices made in the available materials and techniques, whether there is a detectable correlation between materials chosen and the intended function of the objects. Third, whether the characteristics of the objects analysed here be considered to be part of a broader Central Asian artistic and scribal culture. The authors conclude that a local culture of paper and pigment production can be detected in these results, though further research is needed especially on the geographical origin of raw materials for pigments. The results show that artists and scribes made technological choices in paper and pigments depending on the function of the objects they were creating. Finally, understanding of the broader Central Asian context of these results will depend on future analysis of material from other archaeological sites, and comparison with the results of this study.

1. Introduction

Written and illustrated objects are generally produced by the same communities, often by the same people. Yet the academic study of these objects tends to separate the written from the illustrated, with textual items being the province of philology and palaeography, and illustrated material being treated by art historians and archaeologists. This separation of expertise can be obstructive for understanding historical artefacts, obscuring their common social and historical context of production, circulation and disposal. Also too often ignored is the shared materiality of such objects, the local nature of the things out of which they were made.

In this paper we investigate a selection of artefacts from the Central Asia dating from the ninth and tenth centuries. We apply to a range of objects material analysis of paper and pigments, with the aim of describing the similarities and differences between various kinds of illustrated and textual objects, which may fall along entirely different lines from those imposed by textual and art-historical analysis. It is also the authors' intention to test the effectiveness of combining these two levels of scientific analysis (of paper and pigments) with a social analysis of the function of the objects.

In general, when working on historical artefacts (or 'cultural heritage items') there is a tendency for humanities scholars to outsource scientific analysis – usually for the purpose of providing a date or revealing obscured text – and then incorporate the results into their own research. In such cases there is only a minimal interaction between the two parties; the scientist is here merely providing a service, which for the humanities scholar, remains a 'black box'. On the other side, scientists carry out analysis without a coherent research program informed by the cultural content of the texts. In the field of manuscript studies, the lack of coherent

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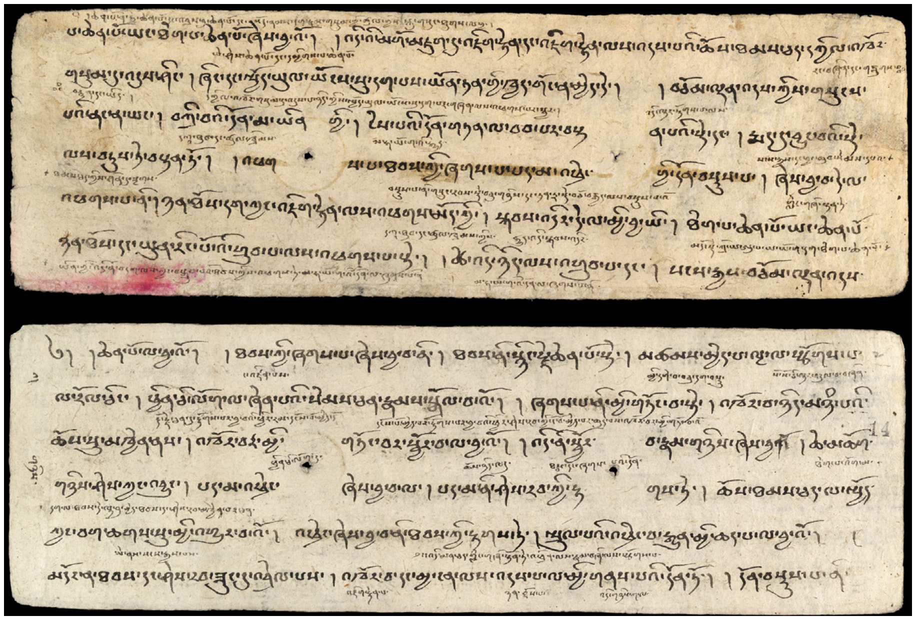

Fig. 1. Folios 1v and 2r of IOL Tib J 709.

scientific research programmes has been highlighted by Neate and Howell (2011: 9):

> Opportunities have not been made to investigate objects, and answers have not been forthcoming for this reason. This makes it difficult for end users to formulate questions which analysis could help answer, and to see where the information could be usefully applied. We have a kind of "chicken and egg" situation.

A number of conceptual frameworks for combining scientific and socio-historical analysis have been proposed; one of the best examples is that of Sillar and Tite (2000). In reference to historical ceramics, they identify a chronological sequence for every object of production, distribution, use, re-use and discard. This is also informed by environmental, social and economic contexts on the one hand, and by the physical properties and performance characteristics of the objects on the other hand.

Complementary sets of data enable us to learn what materials were used for objects intended for a variety of different functions. The primary objective of this study, carried out by a curator and historian (SvS) and two materials scientists specializing in paper (AHW) and inks and pigments (RN), is to characterize the

Fig. 2. Folios 1v and 2r of IOL Tib J 709, photographed under normal light and on a light box.

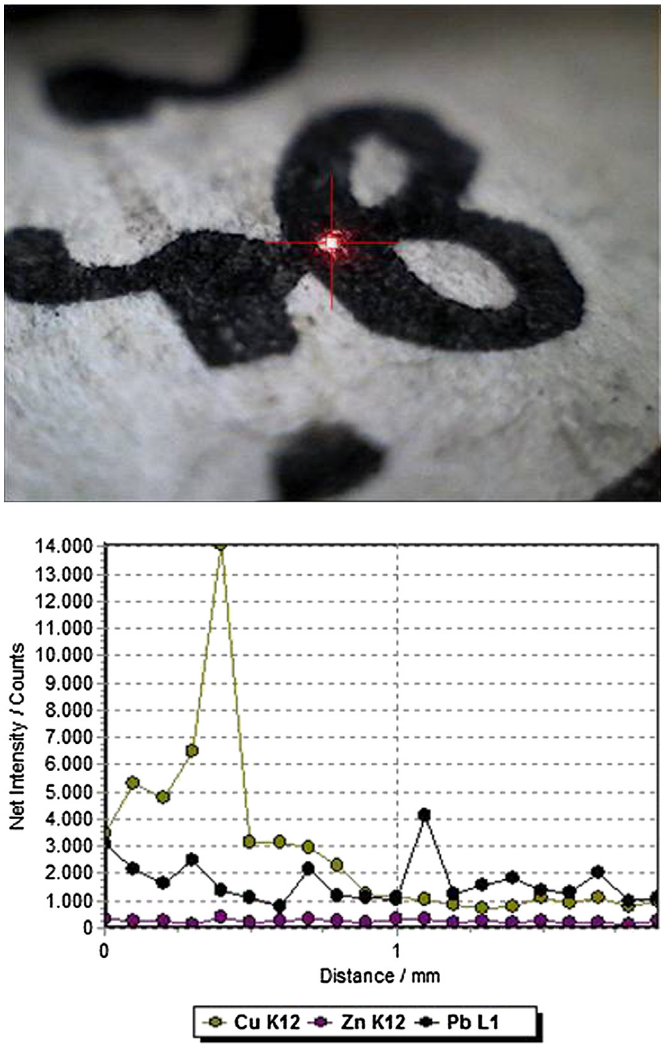

Fig. 3. IOL Tib J 709, XRF-analysis of black ink, magnification 20×. Line scan shows enrichment of Cu in carbon ink.

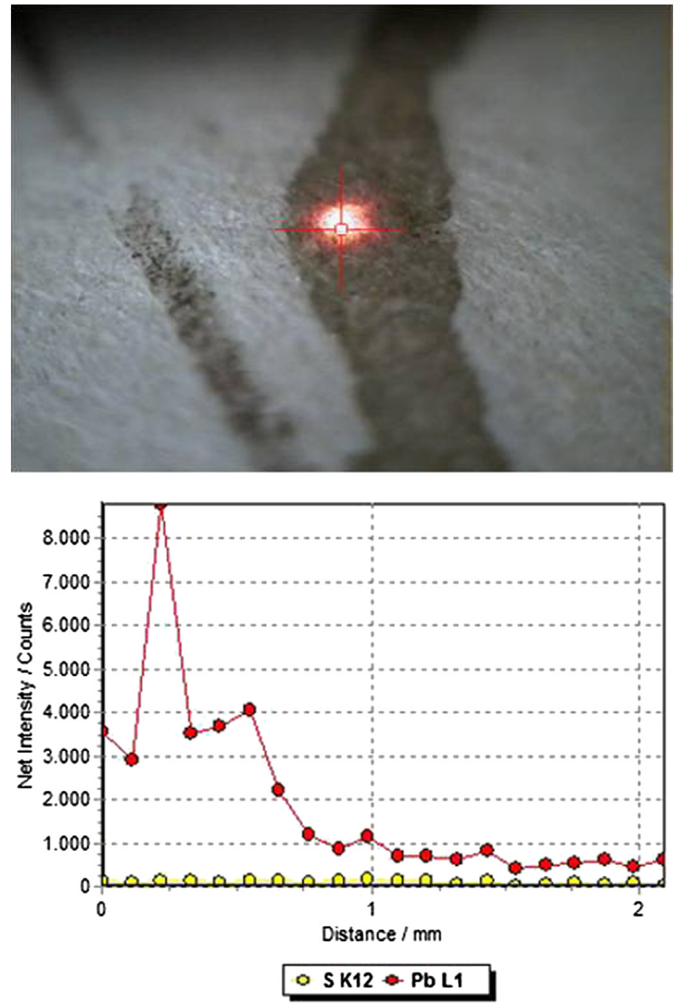

Fig. 4. IOL Tib J 709, XRF-analysis of brown line made out of red lead [Pb_3O_4], magnification 20×. Line scan of the brown ink with Pb. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

composition of the papers and colours in these objects, interpreting this data in terms of their social function. Our analysis of these objects is directed towards two main research questions: First, is there a correspondence between the materials used in the creation of these objects and their geographical origin? And second, in terms of the choices made in the available materials and techniques, is there any correlation between materials chosen and the intended function of the objects?

The objects in this study are all drawn from the Stein Collection kept at the British Library in London. This large collection is the result of three expeditions to Eastern Central Asia led by Marc Aurel Stein in the late nineteenth and early twentieth century. Of the many sites excavated by Stein, the most famous is the ‘library cave’ at the Buddhist cave complex near Dunhuang (in modern Gansu Province, China). The cave, which was sealed at the beginning of the eleventh century, contains manuscripts, paintings and other objects dating from the fifth to tenth centuries; the textual material is written in a variety of languages including Chinese, Tibetan, Sanskrit, Khotanese and Sogdian. The objects analysed here are from the ninth and tenth centuries, encompassing the period of Tibetan rule of Dunhuang (786–848) and the aftermath, in which Tibetan culture was highly influential in the area. The manuscripts considered here are all written in the Tibetan script, and many of the illustrated objects relate to the Tibetan Buddhist religion.

2. Materials and methods

The thirteen objects selected from the Stein collection of the British Library, London, were subjected to analysis of paper, ink and pigments. Paper composition was analysed using an Olympus BX51 Transmitted-Reflected light microscope with BF/DF/DIC/PL, and with an Olympus UC30 camera attached for photographic documentation. Olympus Stream Software was used for image analysis during identification. A varying magnification from 50× up to 600× with both plain and polarized light was applied. Then date and place of analysis was recorded and test locations documented. The sample was placed in a small beaker, immersed in distilled water, and boiled for about 20 min. The water was then decanted and the sample was drained off, defibred into a fine suspension of individual fibres, and placed on the slide. Fibres were observed and then treated with Herzberg stain. Attention was paid to stain colouring, morphology of fibres, and other cells and elements of pulp. Both the width and length of fibres were measured to support identification in particular cases.

Fig. 5. Folio 2 of IOL Tib J 308, photographed on a light box.

Further technological features of paper manuscripts were examined on a light box for paper translucency and papermaking sieve print type. Depending on what type of textile was attached to the papermaking frame, we may observe differences in texture and sieve print. The print of a textile sieve differs clearly from that made of bamboo (laid regular), reed, or other grasses (laid irregular), and when sealed in the paper structure, this allows us to distinguish handmade wove paper and handmade laid paper, characterized by the particular number of laid lines in 3 cm. These can be categorized as: *laid*, *regular* where there is unequivocal clear evidence; *laid*, *irregular* where the pattern is not regular; and, finally, *laid*, *patchy* where the pattern can only be seen in patches of the paper but could not have been made by anything else. The

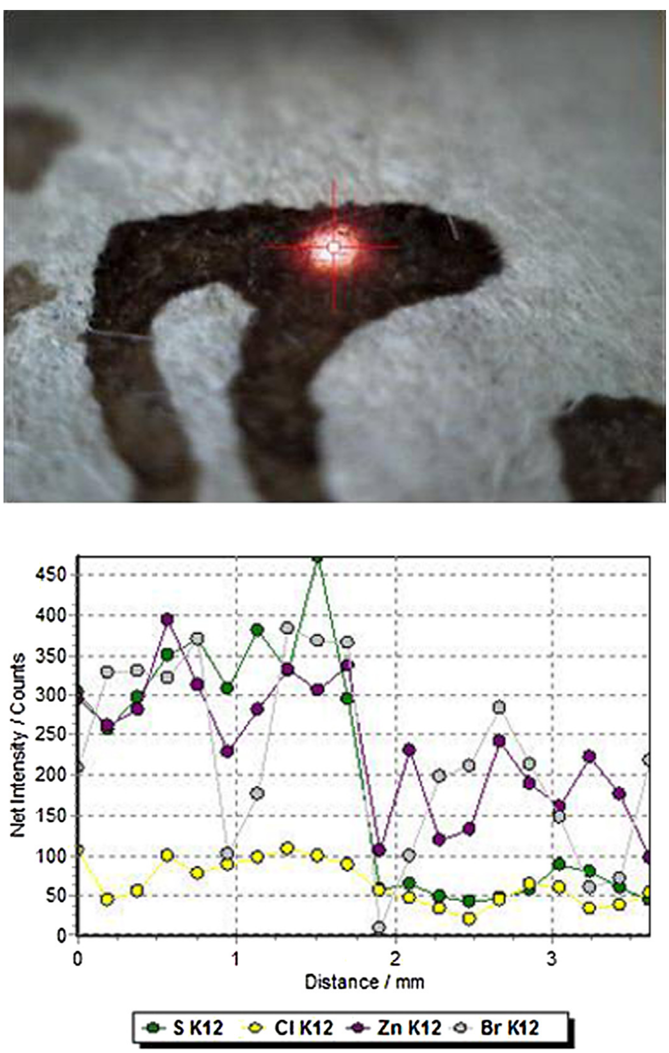

Fig. 6. IOL Tib J 308, XRF-analysis of light brown ink (possibly made of blood), magnification 20×. Line scan showing traces of S–Zn. [sulphur–zinc]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

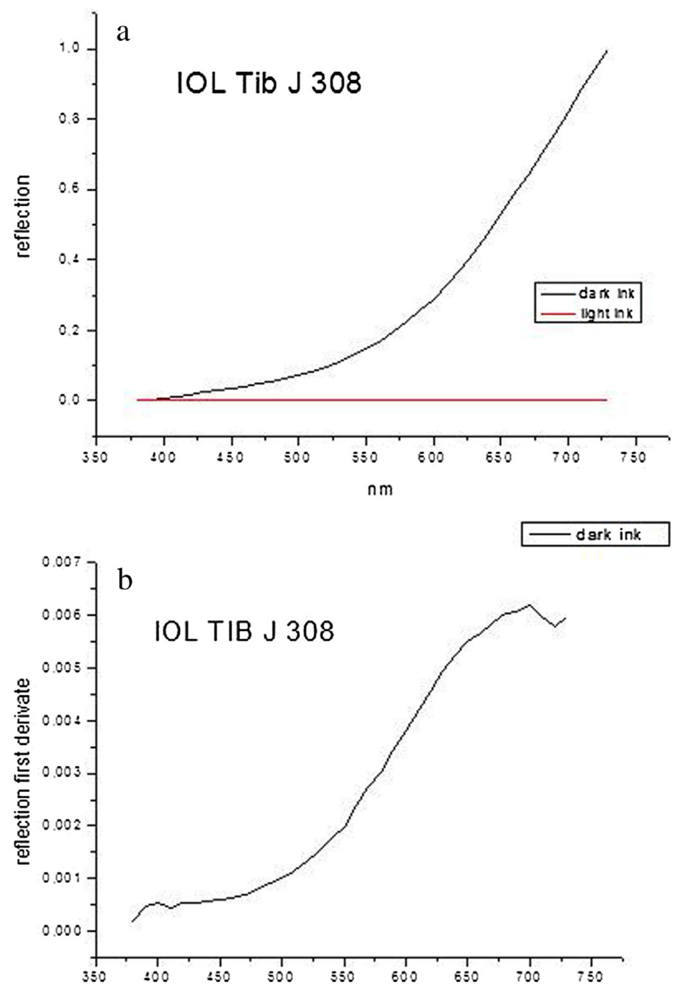

Fig. 7. IOL Tib J 308 VIS- spectra of brown inks (colour curve-graph above. 1st derivation of the colour curve-graph below). The light brown ink (red line) does not show a crystalline structure in contrast to the darker ink (black curve) made out of brown ochre [$Fe(OH)_3$]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

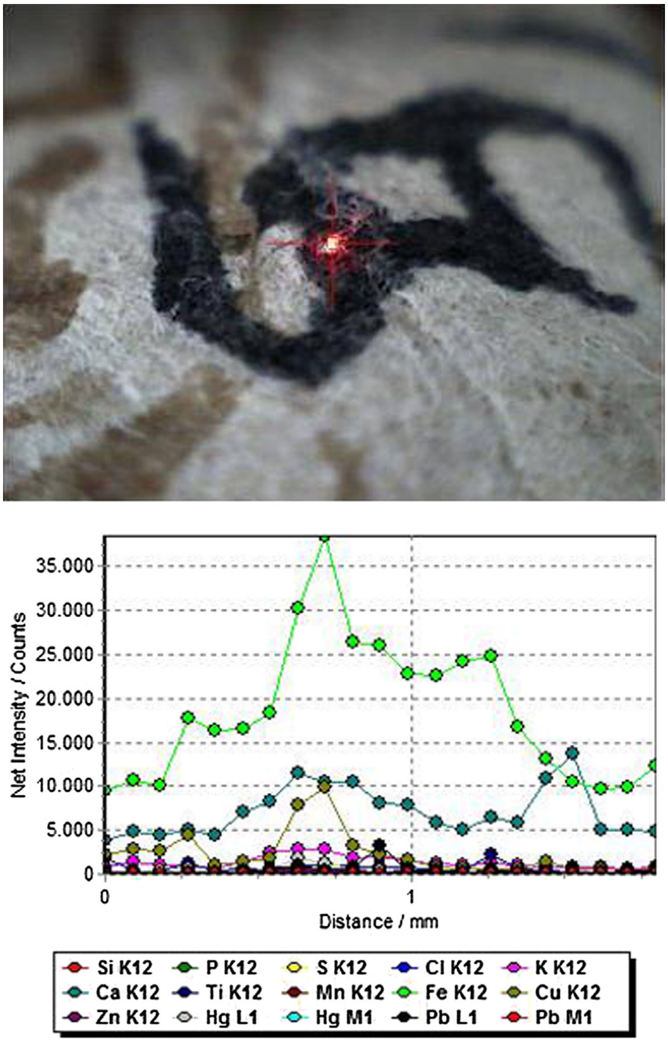

Fig. 8. IOL Tib J 308, XRF-analysis of black ink magnification 20×. Line scan of carbon black ink with Fe–Cu-(K–Hg).

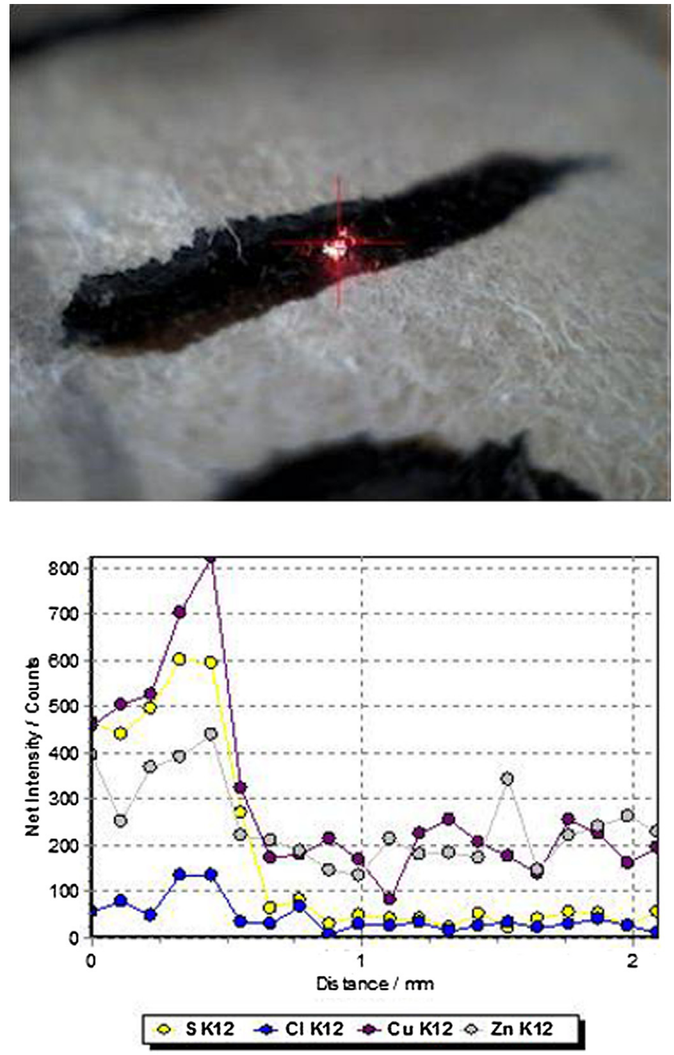

Fig. 9. IOL Tib J 308, XRF-analysis of another black ink, magnification 20×. Line scan shows carbon black ink with traces of Cu–S–Zn.

laid type of mould/sieve is also sometimes characterized by chain lines. These are the vertical lines from the screen on which the paper was manufactured.

If visible on the light panel, the fibre distribution within a sheet was documented. This depends on whether the fibres were poured into the floating mould and distributed by hand or scooped by the mould from a vat, and how quickly drainage of the pulp took place. The presence of uneven pulp thickenings distributed and visible within a sheet of paper, sometimes along the chain and laid lines, sometimes evenly along one edge, also helps determine the type of raw material and methods of its pulping. Paper thickness varies depending on the number of paper sheets glued together or on the technology of paper-making and fibre distribution within a sheet. The usual thickness can vary from 0.01 to 3.5 mm. This is another parameter which helps to classify types of paper. Using a caliper or micrometer, one should measure the paper in at least five different places and give a span value. Paper texture, (e.g. smooth, rough, coarse, polished, highly sized) has also been described where possible. These qualitative features are derived from the final methods of preparation of the leaves before writing.

The colours of the inks used for the Tibetan writing and paintings were examined non-destructively and in situ with the

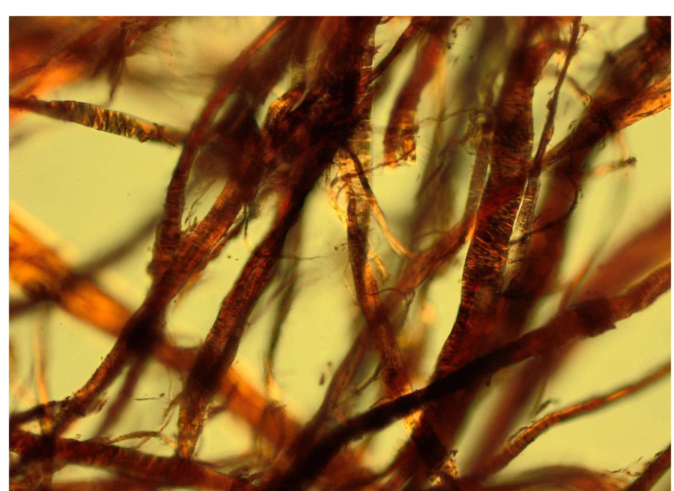

Fig. 10. IOL Tib J 308, rag paper composed of ramie and hemp fibres coloured with Herzberg stain, magnification OM 200×.

Fig. 11. IOL Tib J 1410.

Fig. 12. IOL Tib J 1410 photographed on a light box.

mobile X-ray-fluorescence (XRF) spectrometer ARTAX. This technique allows the identification of the elements of most inorganic pigments of artefacts (Bronk et al., 2001; Snickt et al., 2008). X-rays are generated with an air cooled Mo-tube and an acceleration voltage of maximal 50 kV. All measurements are performed at 35 kV, 0.6 mA and with an acquisition time of 200s (live time). The primary X-rays are focussed by means of a polycapillary X-ray lens, resulting in a measuring spot size with a diameter of ca. 50 μm. The measuring head has a colour CCD camera (500 × 582 pixels) with a 20 times magnification, allowing the exact positioning of the spot. All XRF-spectra are collected using an Xflash™ detector. Working with Helium purging allows the direct determination of light elements from Na (11) to Ar (18).

For further analyses of the colourants, especially to distinguish organic dyes such as indigo from other blue pigments and to classify red pigments, the investigation was complemented with visible spectrophotometry (VIS). The colour spectrometer SPM 100 (Gretag-Imaging AG, Regensdorf, Switzerland) analyses the reflection of the visible light (from 380 to 730 nm). It allows the measurement of a spot of 3 mm diameter. By extending the head, the surface of the sample is illuminated for half a second, using a small 2 W bulb. The characteristic reflectance spectrum is measured and stored (Fuchs, 1988). By comparing this specific spectrum with a database, it is possible to identify most of the colourants—organic as well as inorganic materials.

3. Results and discussion

The illustrated objects in our sample represent a variety of artefacts, both textual and illustrated. Based on their content and function, the objects are discussed in the following categories:

(i) Buddhist manuscripts
(ii) Official letters
(iii) Hung paintings
(iv) Ritual items
(v) Banners
(vi) Stencils and preliminary sketches

3.1. Buddhist manuscripts

Three manuscripts were analysed, all in the *pothi* format. This book form is composed of oblong loose-leaf pages; the paper pothi books of Central Asia and Tibet are thought to derive from Indian palm-leaf manuscripts.[1] The first of the three manuscripts, IOL Tib J 709 (Fig. 1), is a compendium of texts associated with the Chan (Japanese *Zen*) branch of Buddhism, which was an important aspect

[1] See the discussion of pothi and other Central Asian book forms in Whitfield 2004: 216–219.

Fig. 13. The seal at the bottom right of IOL Tib J 1126, under normal light, and on a light box, showing the laid lines of rag paper with ramie.

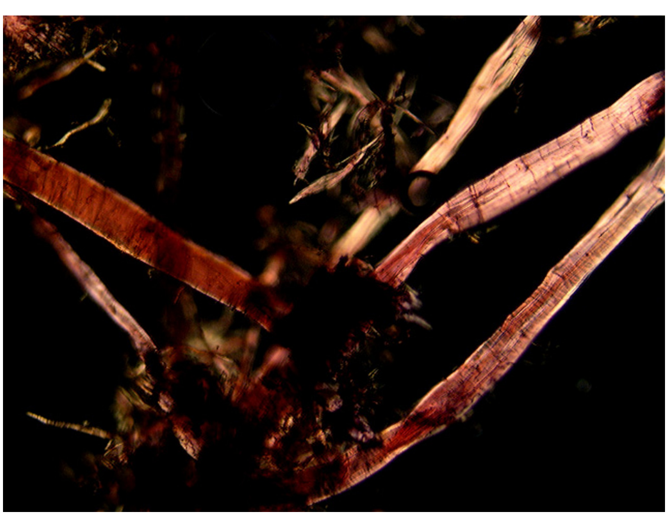

Fig. 14. Rag paper of ramie and hemp fibres coloured with Herzberg stain in IOL Tib J 1126, magnification OM 300×.

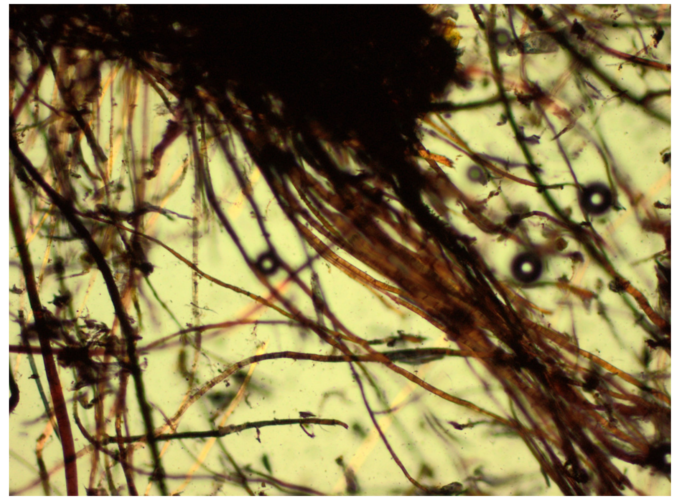

Fig. 15. Two-layered, wove paper of Or.15000/513 made of a mixture of fibres including *Daphne* or *Edgeworthia sp.*, paper mulberry and hemp coloured with Herzberg stain, magnification OM 100×.

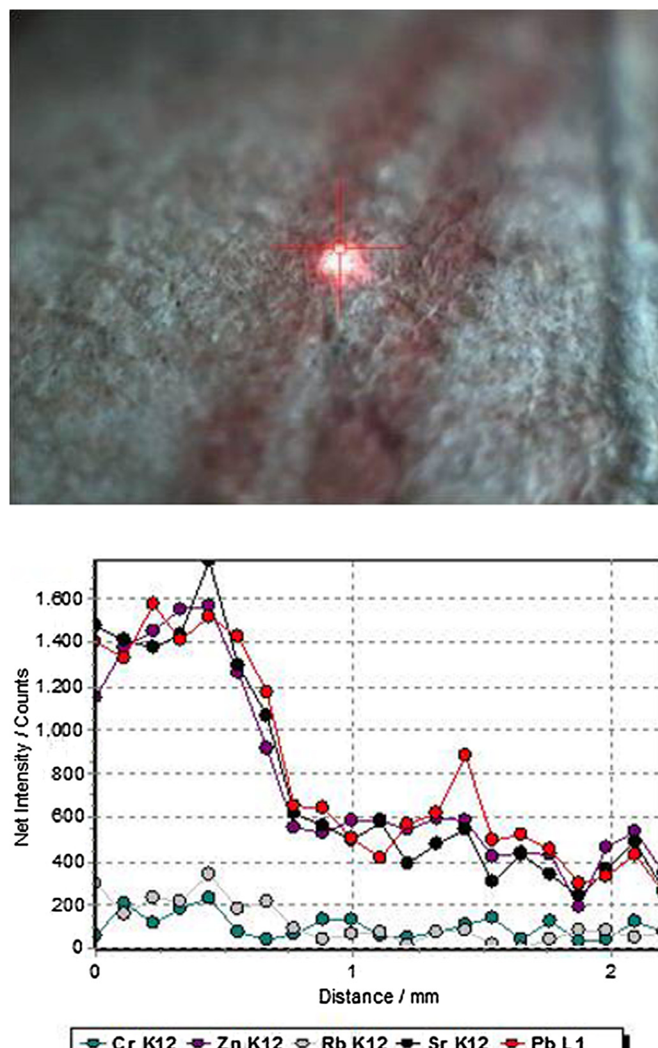

Fig. 16. IOL Tib J 1126, XRF-analysis of stamp, magnification 20×. Red ink is made out of cinnabar [HgS]. Line scan of trace elements Pb–Zn–Sr. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

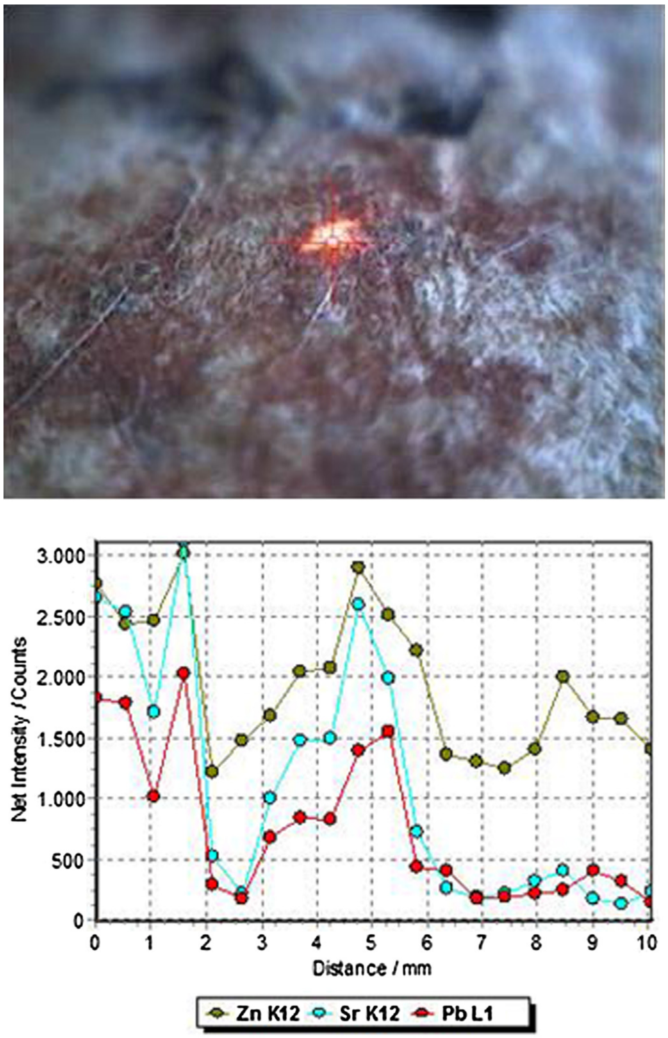

Fig. 17. Or 15000/512, XRF-analysis of red stamp, magnification 20×, with ink made out of cinnabar [HgS]. Line scan of trace elements Zn–Sr–Pb. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

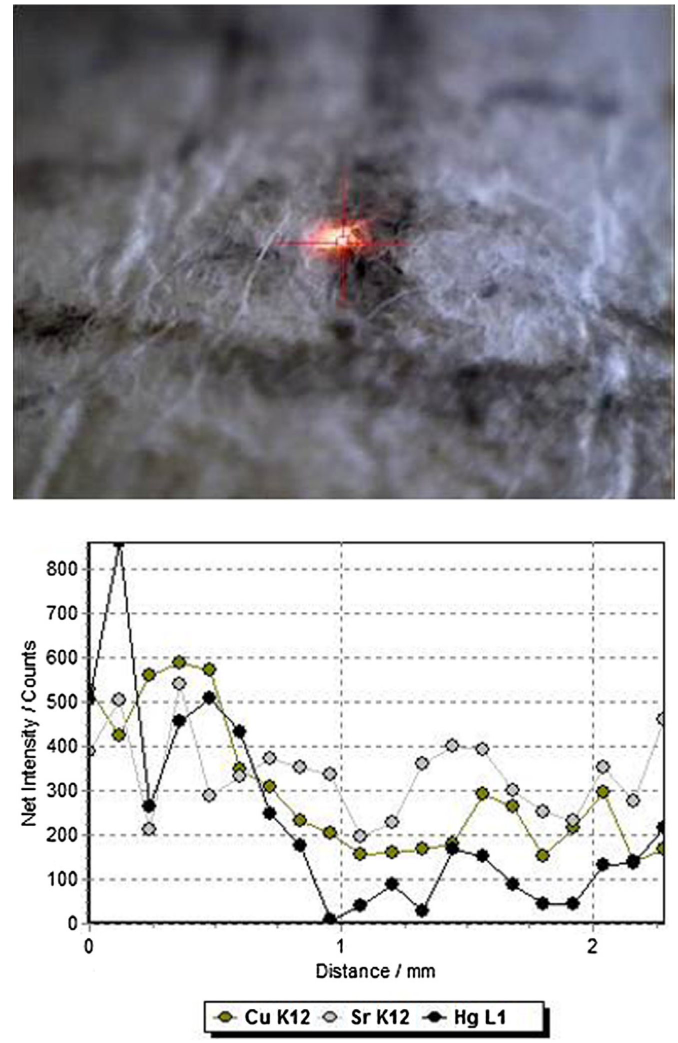

Fig. 18. Or 15000/513, XRF-analysis of brown stamp, magnification 20×, with ink made out of red lead [Pb_3O_4]. Line scan with traces of Sr–Cu–Hg. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of Tibetan Buddhism in the 9th and 10th centuries. The handwriting of this particular manuscript indicates a 10th century date.[2]

This manuscript has the usual combination of black script and red/brown lines separating a margin and circles around string-holes. The black ink is analysed as carbon black enriched with a copper compound (Fig. 3). Copper is often added as an antioxidant or stabilizer of the colour in black inks (Winter, 1983). The red/brown ink is made out of red lead [Pb_3O_4] as the main component (Fig. 4), which indicates, that writing the text was completed on a paper, prefabricated with lines in a different process.

The paper is composed of paper mulberry fibres. A previous study of the Tibetan manuscripts from Central Asia (Helman-Ważny and van Schaik, 2013) showed that those composed of paper mulberry fibres may have been made in the eastern Tibetan cultural area, where paper mulberry is a readily available material. However, as those manuscripts were generally made on a textile mould, and IOL Tib J 709 was made with a movable type of mould equipped with a sieve made of bamboo, characterized by 21 laid lines in 3 cm, it is more likely that the paper for this manuscript came from central China where papermaking sieves were usually constructed with thin bamboo or reeds. (Fig. 2) This paper is constructed of two or three layers glued together and the surface is polished before writing.[3]

Another manuscript, IOL Tib J 308 (Fig. 5), was analysed because of its unusual ink colour. The manuscript is incomplete, but it is clear that it previously contained at least two copies of the *Aparimitāyurnāma-sūtra*. This scriptural text was one of those traditionally copied as a meritorious activity associated with the achievement of a long life. During the 830s–840s, many hundreds of copies were made at the behest of the Tibetan emperor; however

[2] The palaeographical datings in this paper are based on the system outlined in van Schaik (2008).

[3] The process of polishing is applied to make the paper surface even, slightly glossy and less absorbent, which is the surface most conducive for writing with pointed tool. When examining manuscripts this feature corresponds to texture. This, however, is qualitative, but still it can be an important indicator of the preparation techniques of paper before writing. In Tibet for example a conch shell is considered being the best tool for smoothing paper. On the technique of polishing paper, see Hunter 1978: 196–199, Helman-Ważny 2014: 40–41.

Fig. 19. IOL Tib J 1366, recto and verso under normal light.

the present copy is different from these in format and writing style and appears to be a more personal effort. In terms of dating, the small, square style writing is consistent with styles from the Tibetan imperial period, so the manuscript may date from around the same time as the imperially-sponsored *Aparimitāyurnāma-sūtra* scrolls.[4]

Most of the writing in this manuscript is in a brown ink varying between a light colour and a darker colour with a clotted appearance. Black ink has also been used to clarify some of the letters, add corrections, and for the ornamental opening curl on each page and the page numbers (actually the letters *a* and *ha*) in the right margins. It is possible that the brown ink used for the majority of the text is evidence of the practice of writing with blood, which is attested in colophons and other sources.[5]

Results of the XRF-analysis show that the light brown ink of IOL Tib J 308 is enriched with Iron, Calcium, Potassium, Titanium, Sulphur and Zinc [Fe–Ca–K–Ti–S–Zn] (Fig. 6). VIS-spectroscopy does not show any crystalline structure, indicating that there is no mineral pigment in this ink. If no other organic brown sourced from plants was used for the fabrication, then there is a good possibility that the manuscript was written with blood as a large component of the ink; further analysis, such as a forensic test using chemoluminescence, may help to confirm or disprove this. In contrast to this, the darker brown ink is crystalline and made out of brown ochre [$Fe(OH)_3$] (Fig. 7). Furthermore two black coloured inks can be differentiated on the manuscript. One is carbon black enriched with a copper compound. As there are different trace elements in the carbon inks (Fig. 8 and Fig. 9), it can be suggested that the black writing was completed at different times.

The paper of this manuscript was produced from ramie and hemp (Fig. 10) and made with a movable type of papermaking mould equipped with a sieve made of bamboo. Thus this paper represents laid, regular paper with a sieve print characterized by 16 laid lines in 3 cm; the laid lines are horizontal and parallel to the text. Microscopic study shows the exceptionally good quality of fibres derived from high quality textiles. Helman-Ważny and van Schaik (2013) have shown that this is the most common paper type found in the Tibetan manuscripts made in the Dunhuang area. Thus this was probably a locally produced manuscript.

The third manuscript, IOL Tib J 1410 (Fig. 11), was chosen as one of the most richly decorated Tibetan manuscripts in the Stein

Fig. 20. IOL Tib J 1366, verso on a light box.

[4] On the imperial sponsorship of sutras during the Tibetan dynastic period, see Iwao 2012.

[5] The practice of writing in blood has been discussed in the context of Chinese Buddhism by Keischnick (2000) and Jimmy Yu (2012). In the Tibetan context, Wangchuk (2010; not published) reports an edition of the Prajñāpāramita scriptures called the *'Bum dmar* (Red [Prajñāpāramitā] in 100,000 Lines) written with the 'nose-blood' (*shangs mtshal*) of Śāntarakṣita, Padmasambhava, and Khri srong lde btsan.

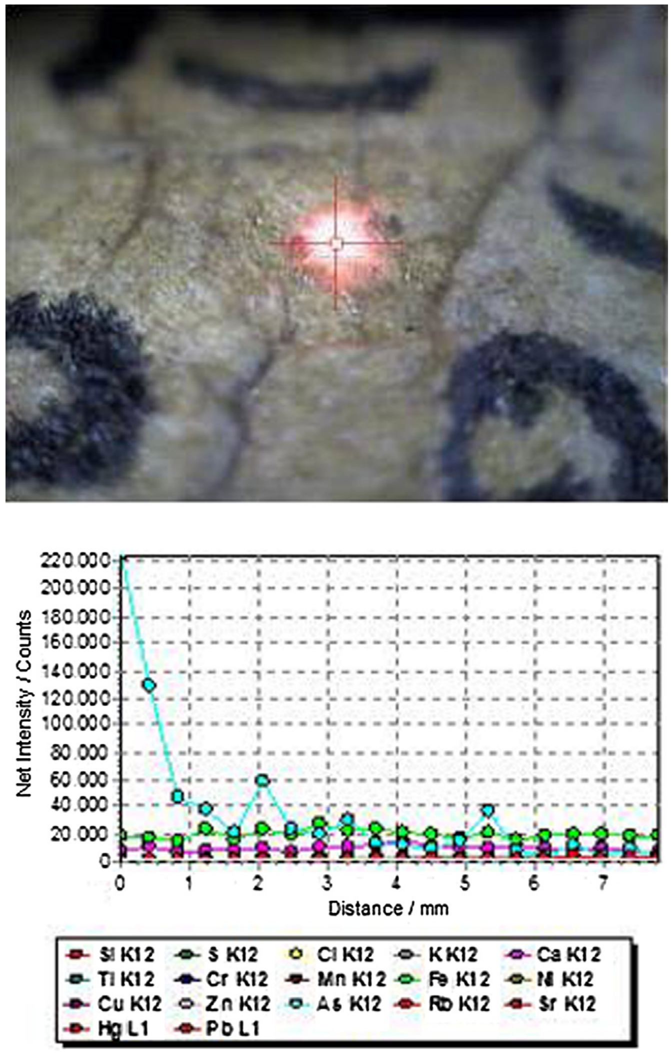

Fig. 21. IOL Tib J 1366, XRF analysis, magnification 20×. Black line is carbon black with a Cu-compound. The yellow body of the Buddha is painted with orpiment [As_2S_3]. Line scan of As. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

collection. It is a single folio in the pothi format, with lightly coloured figures of Buddhas on the margin of the text. The text is a Chinese sutra, the shorter *Sukhāvatīvyūha*, written in the Tibetan script. IOL Tib J 1410 was originally part of a larger manuscript made of two layers of paper that also incorporated five other sheets now catalogued as IOL Tib J 1405–1409. Of these, IOL Tib J 1405 and 1406 are the bottom sheet of the original manuscript, containing Tibetan text on the recto (which was previously covered), and Chinese text on the verso. IOL Tib J 1407–1410 are the original top sheet of the manuscript. The hidden Tibetan text was another copy (though not identical) of the same sutra; the reason for its being covered in this way is not clear. The Chinese text on the verso of the original manuscript is a prayer for the members of a club, and a lamentation to be read at a funeral.[6]

A long colophon states that the scribe comes from the lands of the Kyrgyz (Tib. *gir kis*) and copied several Buddhist texts including

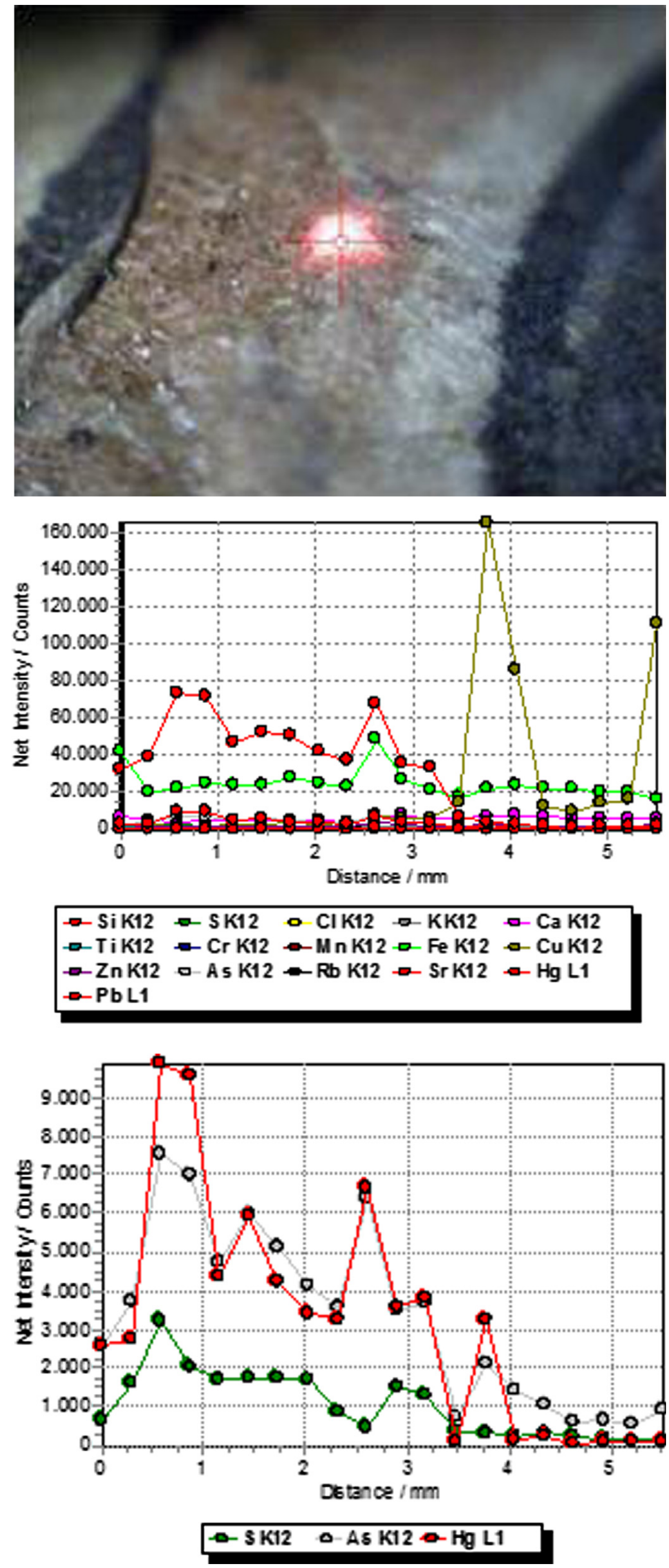

Fig. 22. IOL Tib J 1366, XRF analysis, magnification 20×. The rose colour of the Buddha and the flames consists out of red lead mixed with orpiment and cinnabar. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

[6] See entry C 113 in Enoki's catalogue of Chinese texts in de la Vallée Poussin (1962).

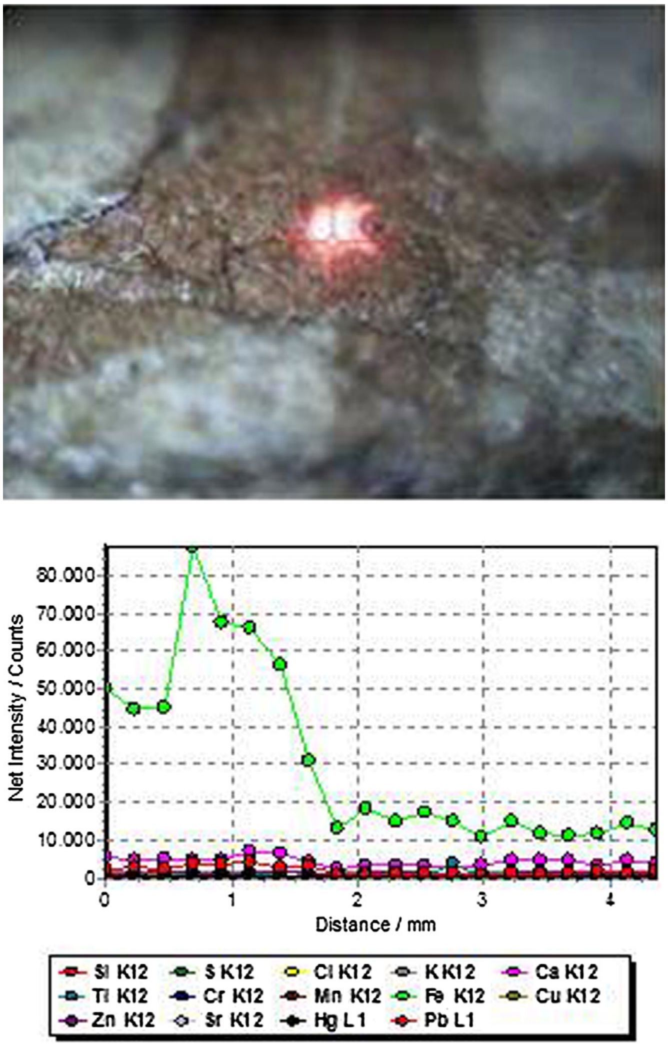

Fig. 23. IOL Tib J 1366, XRF analysis, magnification 20×. The brown lines of the animal are made out of red ochre [$Fe(OH)_3$] with little Pb–Hg. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

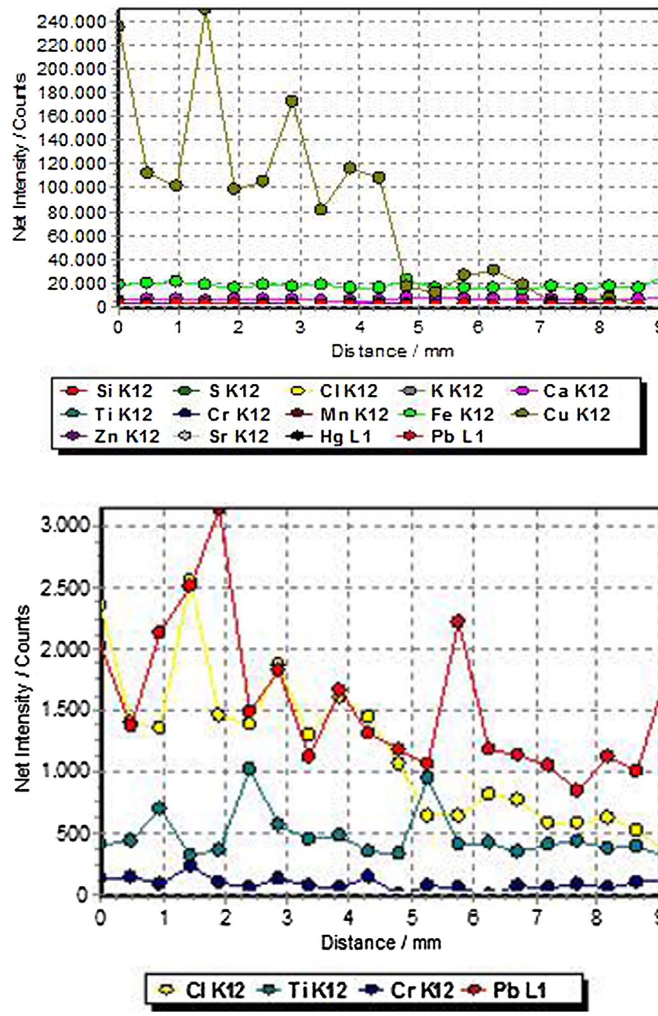

Fig. 24. IOL Tib J 1366, XRF analysis of the green colour, probably atacamite [$Cu_2Cl(OH)_3$]. Line scan with Cu–Cl. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

this one as an offering to the Buddhas, by the merit of which he hopes to return to his homeland (Thomas and Clauson, 1927). This would indicate a date of the late 9th or 10th centuries, when there was an increasingly significant Turkic presence in the Dunhuang area due to the collapse of the Uighur Turkic empire. The handwriting style of this manuscript is consistent with this dating, as it is clearly a post-imperial writing style.

Interestingly the single folio of IOL Tib J 1410 is constructed of two clearly different types of paper (Fig. 12). Despite the fact that both are woven type they differ in raw material, fibre distribution, degree of pulp grinding and surface preparation. The rough panel measuring 26.5 × 37.8 cm on the left side is made of long fibres of ramie and hemp rags with the addition of flax. The soft panel measuring 26.5 × 31 cm on the right side is made with short and rigid fibres of paper mulberry with the addition of silk. This juxtaposition of two very different papers may suggest shortage of materials in the region, or that this particular scribe/sponsor lacked the means to procure large sheets of new paper.

In the illustrations the main pigment used for red and brown is red lead [Pb_3O_4] mixed with cinnabar [HgS]. The light colours show many hues, which were probably created through the dilution of inks. Light brown or yellow is made out of the mineral pigment orpiment [As_2S_3], which shows traces of mercury [Hg], chromium [Cr] and barium [Ba]. The green colour is based on a copper–green pigment [with Cu–Fe–Zn–Ca–Mn–K–Ti–Cr], the blue is probably indigo, enriched in Ca–Zn–S–Cl. Since there are no differences in the usage of pigments on the right and the left side of the manuscripts, it appears that the painting of the Buddhas on the margins was completed at around the same time, despite being on two different kinds of paper. Given this fact and the appearance of the same Tibetan handwriting throughout, it seems that the manuscript was produced in its composite form, which is perhaps linked to its intended use as an offering to the buddhas.

3.2. *Official letters*

Three letters were analysed, one from the Dunhuang area, one from the Miran fort in the Lop Nor desert, and one sent from central Tibet to the Miran fort. All of the letters were originally folded into a rectangular shape, and though they are now kept flat the original folds can still be seen. All three letters can be dated to the second period of Tibetan dominance of Central Asia, from the late 8th to mid-9th century.

Fig. 25. IOL Tib J 1364, a ritual object made of glued paper layers on a wooden stick.

IOL Tib J 1126 is a letter from the *bde blon*, the head of the Tibetan administration of the northeastern territories of the Tibetan empire. It is stamped at the bottom right with the *bde blon*'s own seal, which features a mythical bird-like figure (Fig. 13). This letter is written on rag paper made with ramie, characterized by 12–15 laid lines in 3 cm, with a slightly rough surface and uneven fibre distribution (Figs. 13b and 14). The letter from Miran, Or.15000/512, is on a similar type of laid irregular and patchy one-layered paper characterized by 12 laid lines in 3 cm, made out of ramie and hemp. The letter from central Tibet, Or.15000/513, is on quite different paper from that of the Central Asian letters (Fig. 15). The paper is a thicker (0.19–0.21 mm), two-layered, wove type made of a mixture of fibres including paper mulberry, *Daphne* or *Edgeworthia sp*., and possibly some hemp and unidentified fibres.

The different origin of the letters is also reflected in the composition of the ink used in the seals. The ink of the seal of both Central Asian letters is made from natural cinnabar [HgS] that contains traces of zinc and lead (Fig. 16 and Fig. 17). Thus the term *vermilion*, common for artificially prepared cinnabar is not appropriate here. The letter from central Tibet is stamped with a completely different brown-coloured ink made out of red lead [Pb_3O_4], which shows compounds of mercury [Hg] and copper [Cu] (Fig. 18).

3.3. Hung paintings

The majority of the art objects found in the Dunhuang cave are painted on silk, but there is a significant number on paper as well. The latter tend to be less well executed than the former, and may have been created by people who had not received artistic training. The example analysed here is IOL Tib J 1366, a tantric diagram featuring the buddha Vairocana (Fig. 19). The deity is drawn inside a flaming lotus petal shape, above a simple *maṇḍala* containing the deity's seed syllable *oṃ* inside a triangle. Below the petal is an animal, probably meant to represent an elephant, although it is usually the buddha Akṣobhya who sits on an elephant throne. As Vairocana is one of the five buddhas of the tantric *maṇḍala*, this painting may have been one of a set of five; compare the ritual crown Pelliot chinois 4518 (7) in which each of the five buddhas is depicted inside a flaming lotus petal. On verso, there are disconnected sketches of further partial *maṇḍala* shapes and deities.

A clue to the function of this manuscript may be found in the holes pierced along the top and bottom edges of the paper, which suggest that it was hung or suspended on a wall. Similar holes are seen in other illustrated paper sheets, for example, Pelliot chinois 4514 (15), a buddha image with a diagram that may have been a focus for Chan meditation practice. In another example, Pelliot tibétain 1122, an image of the Buddhist deity Vaiśravaṇa, a length of string is looped through one of the holes. This suggests that the paintings may have been hung on a horizontal rod, perhaps with another rod at the bottom to pull the painting flat, similar to the later method of hanging Tibetan thangka paintings. Paintings like this were displayed on the east side of a *maṇḍala* platform in tantric rituals (on the use of such platforms in rituals, see Wang, 2013). Given the rough quality of the painting, it is likely that it was created as a support for a ritual or meditative practice by practitioners rather than by a trained artist.[7]

The paper of IOL Tib J 1366 is rag paper made of ramie and hemp, composed of short fibres, highly damaged and rigid with uneven fibre distribution. This one-layered paper with rough surface is the laid irregular type characterized by 12–13 laid lines in 3 cm, and chain lines at intervals 7.5, 8.2 and 8.8 cm (Fig. 20). The paper is characteristic of locally-produced Dunhuang paper from the 8th to

[7] Fraser (2000: 204, 221) also suggests that sketches of tantric subjects among the Dunhuang collections were primarily created as supports for practice.

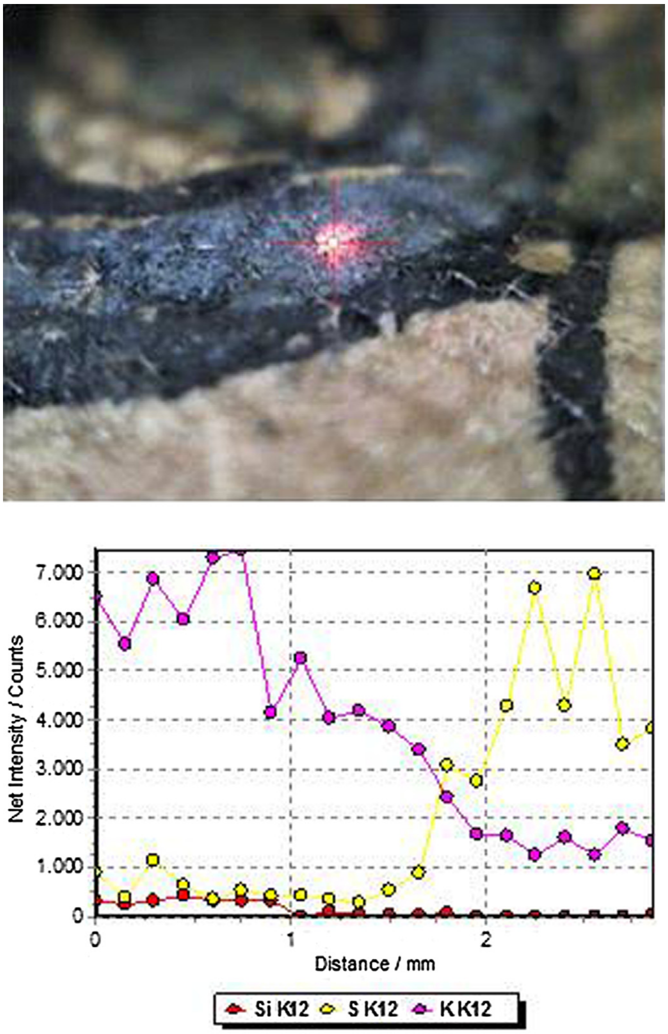

Fig. 26. IOL Tib J 1364, XRF analysis, magnification 20×.The blue colour is indigo. The black line is drawn with carbon ink containing Cu–Hg–S. The line scan shows enrichment of Fe–Ca–K–Si in the blue colour. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

10th centuries. The tantric image itself suggests a date towards the end of this period.

The image was sketched with a black carbon ink enriched in a copper compound (Fig. 21), before it was painted with light colours. The linear figures and symbols on the verso side are drawn with the same black ink. Only the animal figure is drawn in lines with a different brown ink made out of ochre [$Fe(OH)_3$] containing red lead [Pb_3O_4] and cinnabar [HgS] (Fig. 22). The dark red colour round the circles in the petal-shaped frame is a mixture of ochre [$Fe(OH)_3$] and red lead [Pb_3O_4], while the rose colour used for the buddha figure and the flames is a mixture of red lead with a little orpiment [As_2S_3] and cinnabar [HgS] (Fig. 23). The centre of the picture and the yellowish body of the deity are painted with orpiment [As_2S_3], a highly valued pigment (Schafer, 1955). The green coloured background consists out of a copper-chloride based pigment, probably atacamite [$(Cu_2Cl(OH)_3)$], detected with traces of lead and zinc [Pb–Zn] (Fig. 24). Atacamite is a mineral found in nature among copper ore oxidation zones in arid climates.

The chemical components of the inks obviously indicate the process of painting, indicating that the artist did not have a dedicated brush for each colour. Only the green and the yellow applied

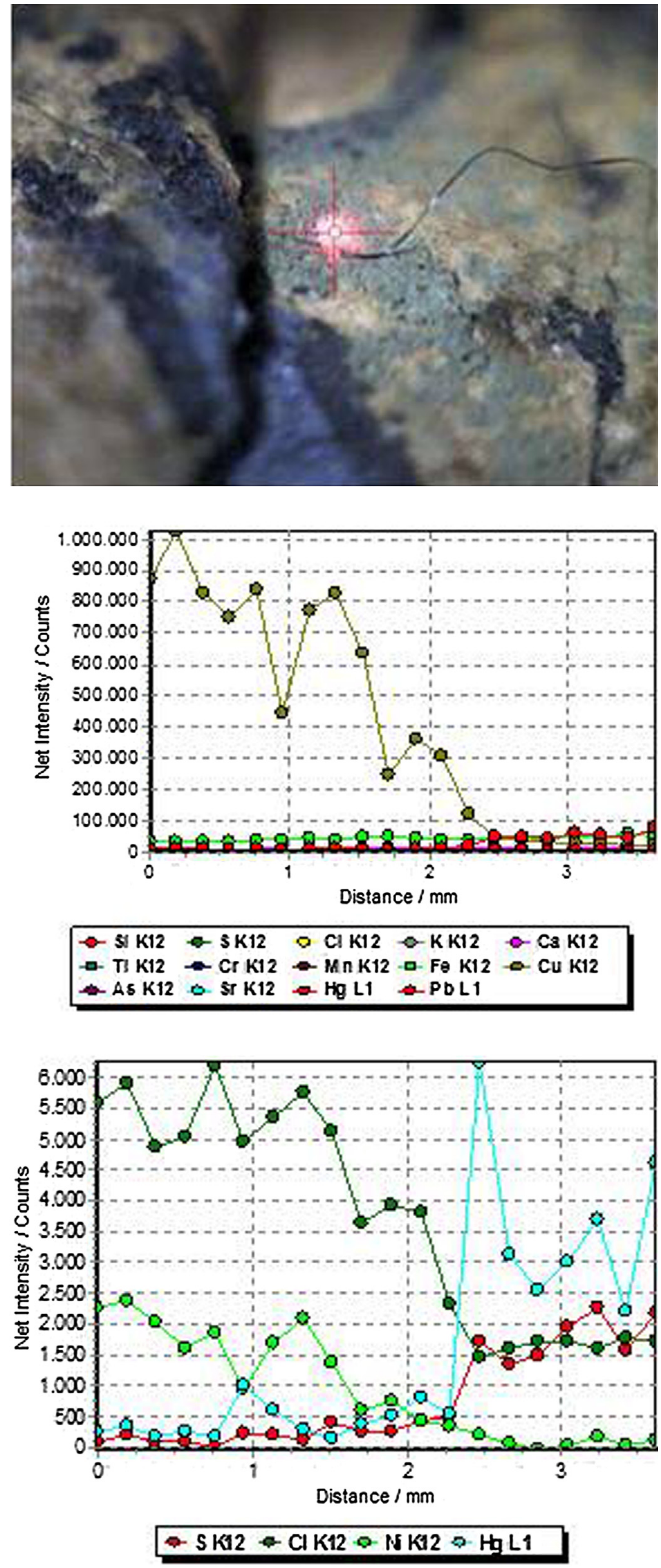

Fig. 27. IOL Tib J 1364, XRF-analysis, magnification 20×.The green colour is atacamite [$Cu_2Cl(OH)_3$]. The line scan shows Cu–Cl and Ni as trace element. The black line (left side of the diagram) shows traces of cinnabar [HgS]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 28. a, b. IOL Tib J 1362, photographed under normal light and on a light box.

in the centre and for the Buddha show pure pigments. We suggest therefore that these colours were painted with a clean brush at the beginning of the work. Then the rose colour of the Buddha and the red flames were painted with the brush used before for yellow, adding red lead and little cinnabar [HgS]. A clean brush was then taken for the dark red petals of the frame completed with ochre and red lead. For painting the animal, this brush was then put into the rose colour.

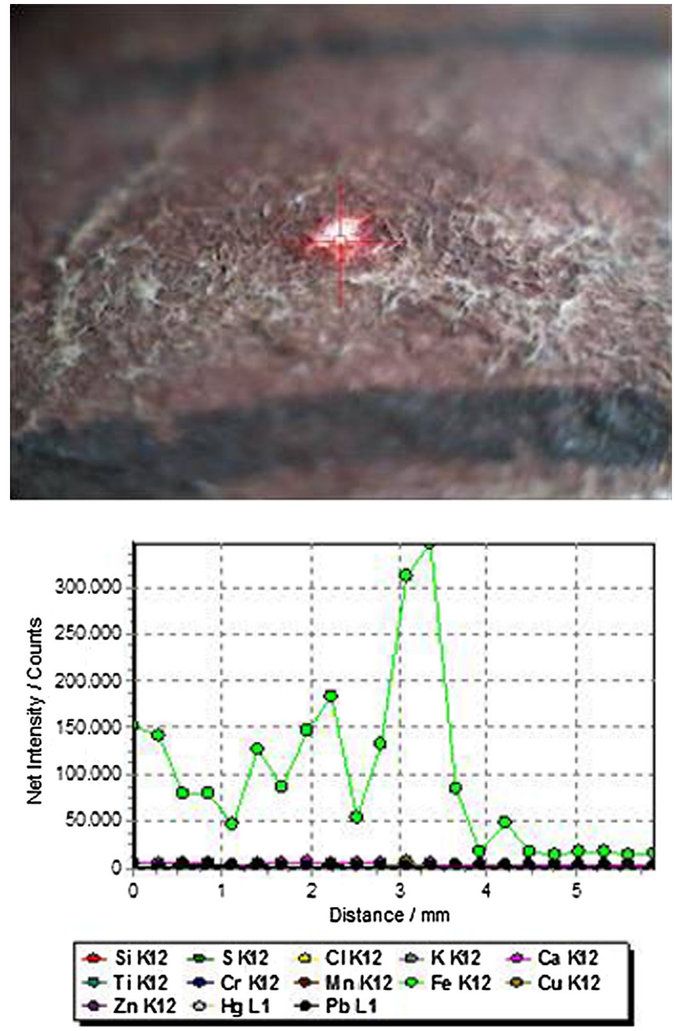

Fig. 29. IOL Tib J 1362, XRF-analysis, magnification 20×. Brownish red colour of the robe with red ochre (iron oxide). Line scan with Fe(Pb). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.4. Ritual items

IOL Tib J 1364 is an octagonal paper structure mounted on a pointed stick (Fig. 25). It probably had a ritual use, similar to the *tsakali* used in modern Tibetan tantric empowerment rituals. The object could have been placed on a shrine or *maṇḍala* and held up during the relevant part of the ritual. The object is decorated with a linear black drawing and painted within those lines with green and blue. The figure on the front of the object can be identified from textual sources as Vajrasattva, the primary deity of the *mahāyoga* genre of tantric practice (van Schaik, 2008).

This ritual item is constructed with many layers of ramie and hemp rag paper glued together. The surface of the paper is rough with texture of textile or felt probably used during joining layers. Due to such construction it is not possible to examine other technological features of this paper. The ink of the drawing is carbon black containing copper and mercury compounds. This leads to the assumption that the black lines were drawn before with red ink made out of cinnabar [HgS]. The blue colour probably is indigo. There is no elemental composition typical for lapis lazuli or a copper based blue (Fig. 26). The green colour is enriched in copper

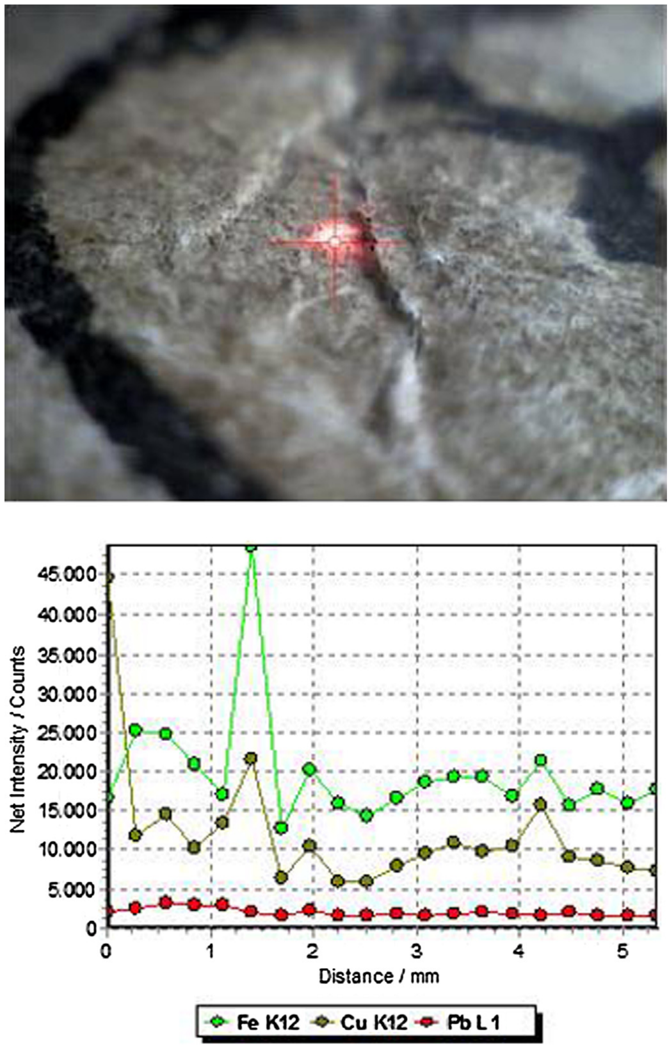

Fig. 30. IOL Tib J 1362, XRF-analysis, magnification 20×. Brownish–red lotus. Line scan of Fe–Cu-(Pb). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

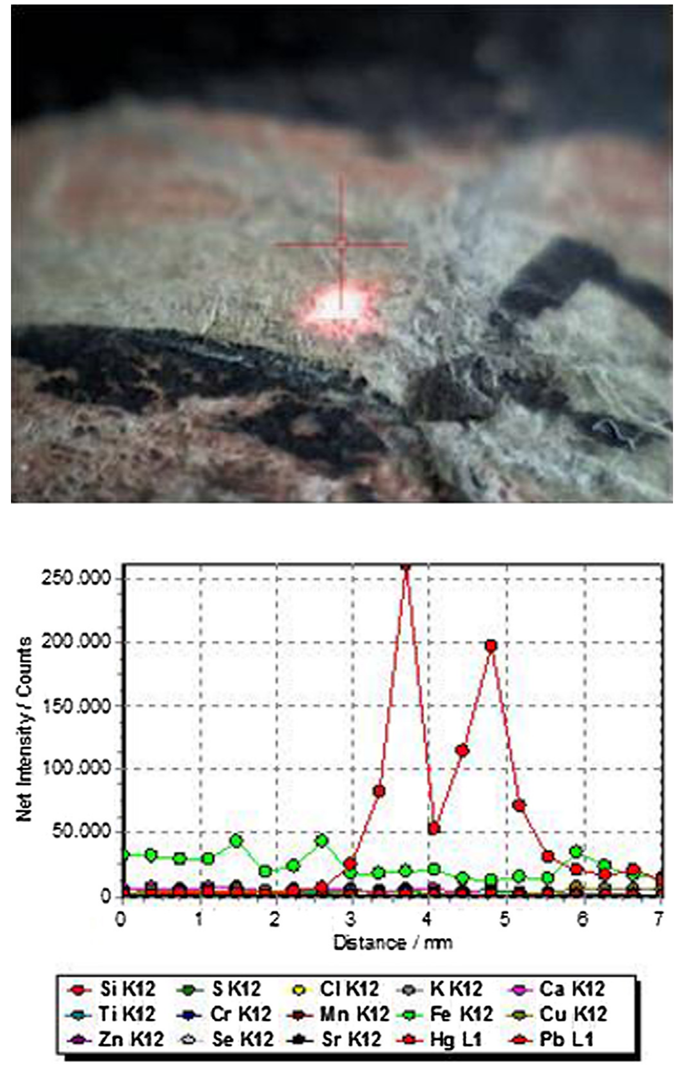

Fig. 31. IOL Tib J 1362, XRF-analysis, magnification 20×. Orange nimbus out of red lead and cinnabar. Line scan with Pb (S–Se–Hg). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and chloride, which indicates the use of atacamite [$Cu_2Cl(OH)_3$] (Fig. 27). The slightly brownish colouration in between the coloured fields is based on an ink consisting of artificial red lead [Pb_3O_4] transformed to brown PbO_2. It shows traces of mercury, similar to those in the black ink. Probably the brush was used before for a red colouration with cinnabar [HgS].

3.5. Banners

One of the most common artistic objects found in the Dunhuang cave is the temple banner. The finer examples are painted on silk, but there are also banners made from a mixture of paper and silk (for complete examples of the latter type, see Stein Paintings 142–144).[8] We know that some banners had specific ceremonial functions, in which they were created and hung as part of a ritual, such as for curing the sick.[9] Those placed in the Dunhuang cave had probably outlasted their specific ritual function, or as seems to be the case with the banners examined here, were too damaged for use or repair.

IOL Tib J 1362 is a fragment of a paper banner (Fig. 28); the original banner form can be deduced from the margins on each side of the figure and the triangular design above it. The main figure is a Buddha with the right hand in the *vitarka mudrā*. Several of the Dunhuang banners are composed of images of Buddhas and bodhisattvas in a vertical sequence, and this is likely to have been the case here. The Buddha's robes and the tips of the lotus petals forming his seat are painted with a dark red, while his aureola and halo are painted with red, orange and green.

The dark brownish red colour of the Buddha's robe is made out of iron oxide [Fe_2O_3] in a mixture with red lead [Pb_3O_4] (Fig. 29). Traces of copper in the brown–red lotus indicate that it probably was chalked out with a special carbon ink (Fig. 30). The orange nimbus is made out of red lead containing cinnabar [HgS], which is common for the preparation of red inks in Asia (Fig. 31) (Zhan, 2007). The brownish margins are coloured with red lead showing traces of iron, mercury and copper

[8] These can be found under the pressmarks 1919,0101,0.142, 1919,0101,0.143 and 1919,0101,0.144.

[9] On the ritual functions of Dunhuang banners, see Whitfield 1985: 323–4.

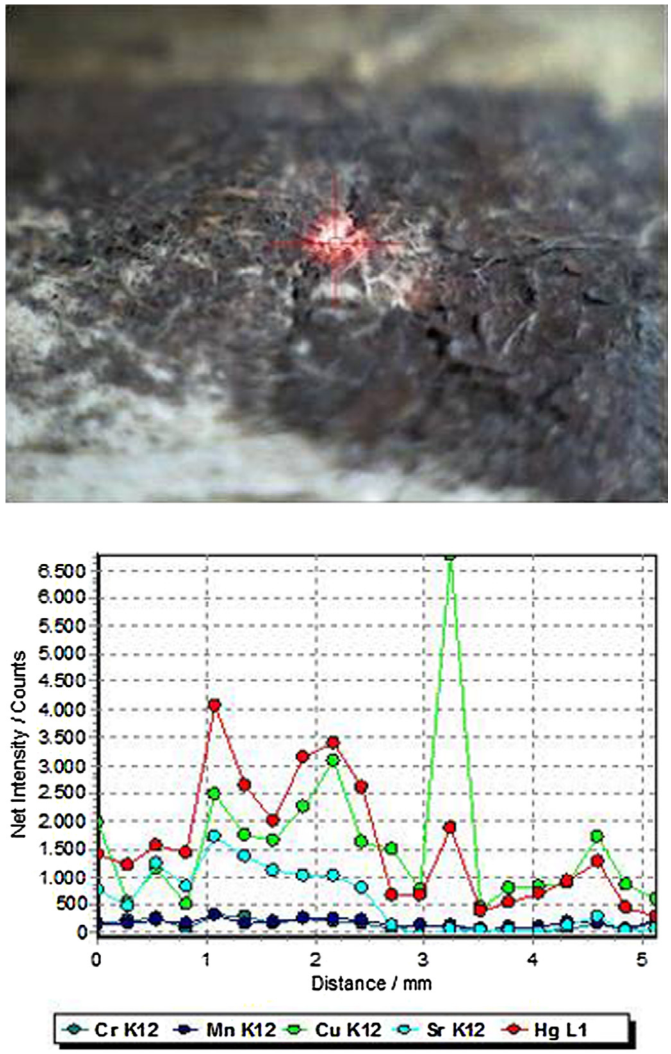

Fig. 32. IOL Tib J 1362, XRF-analysis, magnification 20×. Brown margin with a diluted brown colour. Line scan with Pb–Fe–Se–S–Hg–Cu (here: Hg–Cu). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

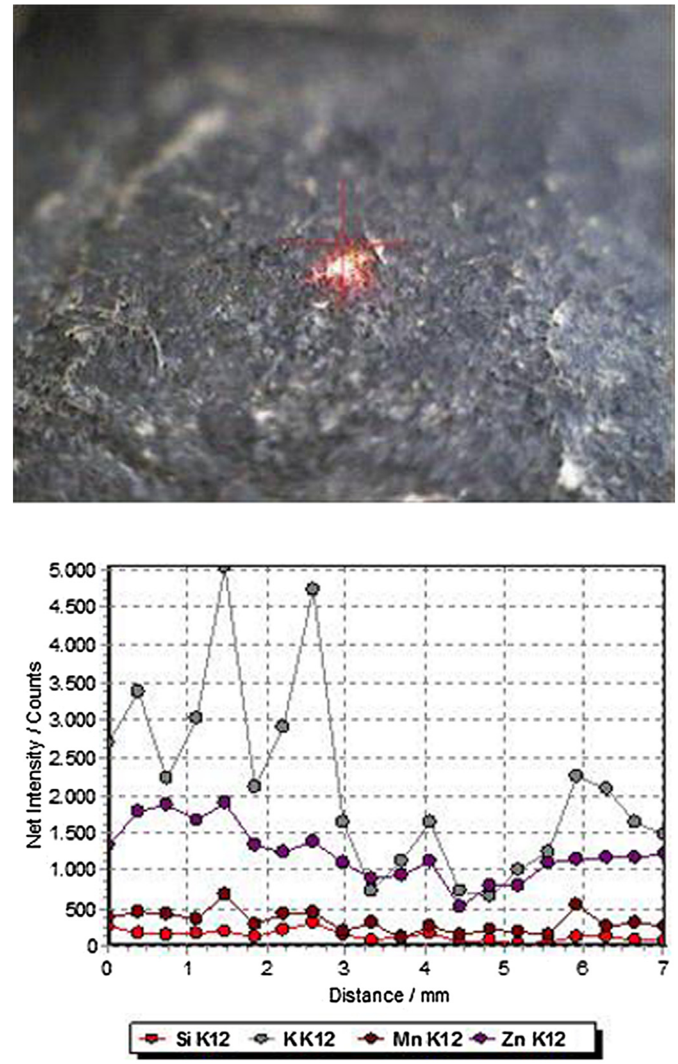

Fig. 33. IOL Tib J 1362, XRF-analysis, magnification 20×. Black hair painted with carbon ink. Line scan showing enrichment in Fe–K–Zn.

[Fe–Hg–Cu], indicating the use of the same brush with residues of ochre [Fe_2O_3], cinnabar [HgS] and black ink [C–Cu] (Fig. 32). The combination of elements in the red–brown inks may also suggest that these colours were achieved by mixing different proportions of pigments together on a palette. The green is identified as atacamite [$Cu_2Cl(OH)_3$] (Fig. 33). Interestingly the black hair of the Buddha is painted in a different carbon black, showing traces of iron, potassium and zinc [Fe–K–Zn] (Fig. 34). The content of zinc detected in the black and green colours suggests that painting them was completed with a separate brush or at a different time to the other colours.

The image is painted on laid irregular paper characterized by 11 laid lines in 3 cm with rough surface and uneven fibre distribution. The long fibres of hemp with possible addition of ramie used as raw material suggest that this paper may have been produced intentionally for this kind of art work.

Another richly illuminated picture constructed with high quality materials is IOL Tib J 1365 (Fig. 35). This shows the lower half of the bodhisattva Avalokiteśvara, standing on a lotus. As in the previous fragment, the wide margins to each side of the figure show that it was previously part of a banner. The bodhisattva's body is depicted clothed in silk of yellow, orange and green. The red lotus is painted with iron oxide [Fe_2O_3], which is identical to the pigment used for the lotus in the previous banner (Fig. 36). Also here different mixtures for the red hues are detected. The brownish red is iron oxide with little red lead [Pb_3O_4], whereas the lighter orange colour consists of more red lead than iron. A mixture of red lead with little cinnabar [HgS] can be detected in brown to orange hues. The yellow of the vase and the robe is painted with ochre [$FeO(OH) \times nH_2O$]. There are traces of lead and mercury in it, so we suggest that it was painted with the same brush used before with the other red colours. The green is made with atacamite [$Cu_2Cl(OH)_3$] containing traces of Zn (Fig. 37). The black lines are made out of carbon ink containing a copper compound. The whole palette of the pigments used in this banner is very similar to that used in IOL Tib 1362 (Fig. 28a).

Concerning the paper, long and highly fibrillated fibres of ramie, hemp, and a small addition of cotton compose a one-layered laid irregular paper characterized by 12 laid lines in 3 cm with uneven fibre distribution.

3.6. Stencils and preliminary sketches

An important subgroup of the illustrated manuscripts from the Dunhuang collections is the artists' stencils and sketches. The

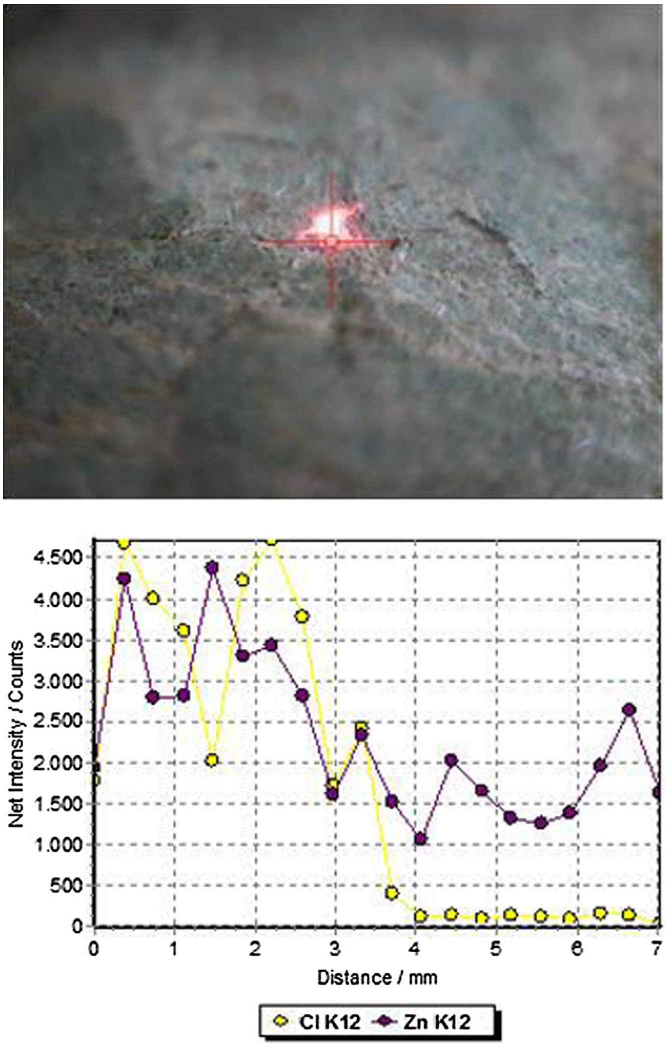

Fig. 34. IOL Tib J 1362, XRF-analysis, magnification 20×. Green colour made out of atacamite [$Cu_2Cl(OH)_3$]. Line scan with Cu–Cl–Zn. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

stencils would have been used in the process of marking out a temple or cave wall for painting, especially for standard and often-repeated forms, like the repeated images of small Buddhas used in the upper portions of many of the caves. The Dunhuang collections contain several stencils of Buddhas, including Pelliot chinois 4517 (2–6) and Stein Painting 73 (2). An unusually complex example, Stein Painting 73 (1) has a central Buddha flanked by an audience of two monks and two bodhisattvas (Fig. 38). The stencil in our sample (IOL Tib J 1361) is a simple Buddha figure, with the lines of the figure sketched in with brown carbon ink with traces of lead- and copper-compounds (Fig. 39).

The artists' sketches have a different function from the stencils. Rather than being forms directly reproduced in the caves, they appear to have been used in the process of preparing designs. Rather than depicting the layout of whole murals, they usually contain elements of the design, such as individual figures or architectural details. The sketch in our sample (IOL Tib J 1363) shows two figures of the deity Vajrapāṇi, facing towards each other in a way that would not have been reproduced in a finished mural; rather these were studies for painting the deity in either left or right facing orientation (Fig. 40). Indeed the paper sheet seems to have been cut vertically at some stage to separate the two figures, and later glued back together again. Further mural elements, a robed woman and architectural details, were sketched on the verso. A very similar sketch of Vajrapāṇi is seen on the scroll Pelliot chinois 2002, along with other sketches including deities' faces and human figures in various positions.

The sketch is painted with a different ink to that of the stencil. Its black colour is due to carbon ink that contains traces of Fe–K–Ti–Zn (Fig. 41). The black ink used on verso of this stencil is made out of pure carbon ink, not showing any impurities, whereas the brownish ink may indicate a previous use of the brush with red lead, seen in its traces of Pb–Cu.

Both the stencil and the sketch in our samples were executed on very similar type of thick (0.23–0.31 mm and 0.24–0.26 mm) paper made of ramie and hemp rags. Both papers are absorbent laid irregular papers with uneven fibre distribution characterized by 11–12 laid lines in 3 cm with rough surface. It is possible that this

Fig. 35. IOL Tib J 1365, photographed under natural light and on a light box.

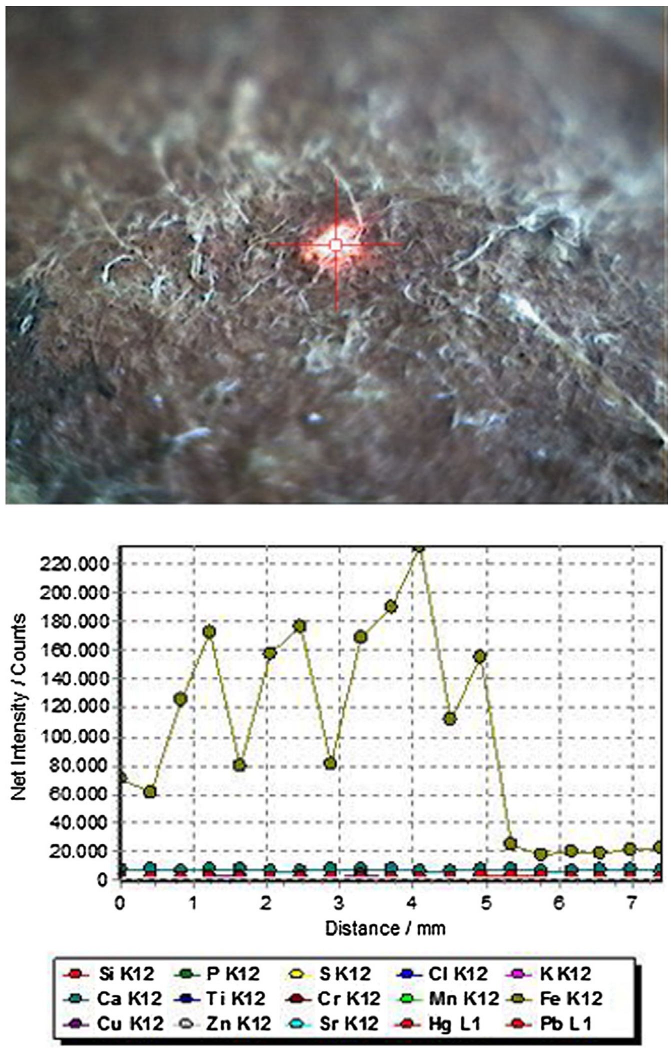

Fig. 36. IOL Tib J 1365, XRF-analysis, magnification 20× of lotus painted with red ochre. Line scan of red iron oxide. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

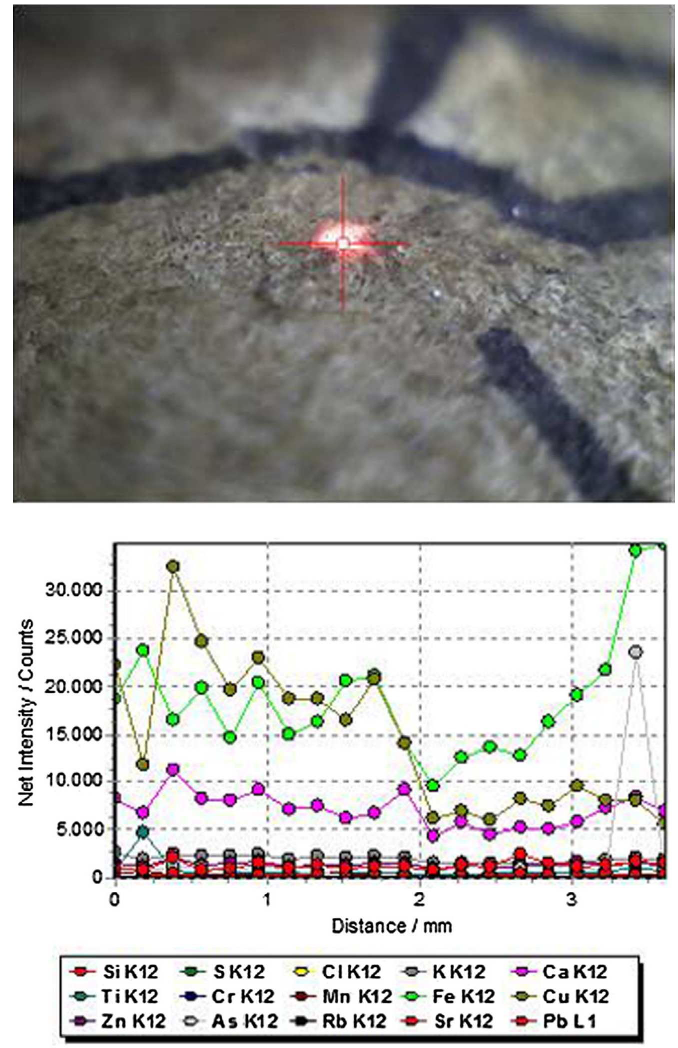

Fig. 37. IOL Tib J 1365, XRF-analysis, magnification 20×. Green colour made out of atacamite [Cu_2 Cl $(OH)_3$]. Line scan of copper. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

kind of one-layered, but thick and absorbent paper was preferred for stencils and sketches.

4. Materials identified: ink and paper typology (Tables 1–4)

5. Conclusions

In this paper we investigated a selection of artefacts from the Central Asia dating from the ninth and tenth centuries, conducting material analysis of paper and pigments, with the aim of describing the similarities and differences between various kinds of illustrated and textual objects. At the outset we asked questions which we intended to address through materials analysis. The first questions related to geographical origin: Is there a correspondence between the materials used in the creation of these objects and their geographical origin? Are there clear characteristics in the materials produced and particular techniques used in the local workshops at Dunhuang as against objects brought from elsewhere?

Paper analysis indicates that most of the material, except the letters, was produced locally. Analysis of colours used for both writing and painting showed a rich selection including yellow, rose, orange, light red, dark red, brown, and black. Mobile-XRF proved to be a valuable analytical method, allowing the identification of almost all pigments by characteristic elements. In cases of doubtful assignments, VIS spectroscopy was a useful complement especially for colouration with organic dyes. Various colour shades have been identified due to the chemical composition of the paint. The pigments red iron-oxide and red lead are detected either pure or in mixtures. However, red cinnabar, a very common pigment in China, was only detected together with other colours and in the ink of a seal. Also characteristic in the objects tested here is the use of orpiment as a yellow pigment to paint special parts as the nimbus of a buddha. The blue and green pigments are indigo as a common blue dye and copper based green atacamite, that is also a widespread pigment in Asia.

Writing and drawing is completed with a wide variety of brown and black inks. The black ink is usually made of carbonized plants or soot, as exemplified by the typical Buddhist manuscript IOL Tib J 709. Ink can also contain other organic components that can modify its properties where needed. The unusual organic compounds in the ink in manuscript IOL Tib J 308 indicate that blood may have been an element in its composition. In letters written in Central

Fig. 38. IOL Tib J 1361, photographed under normal light and on a light box.

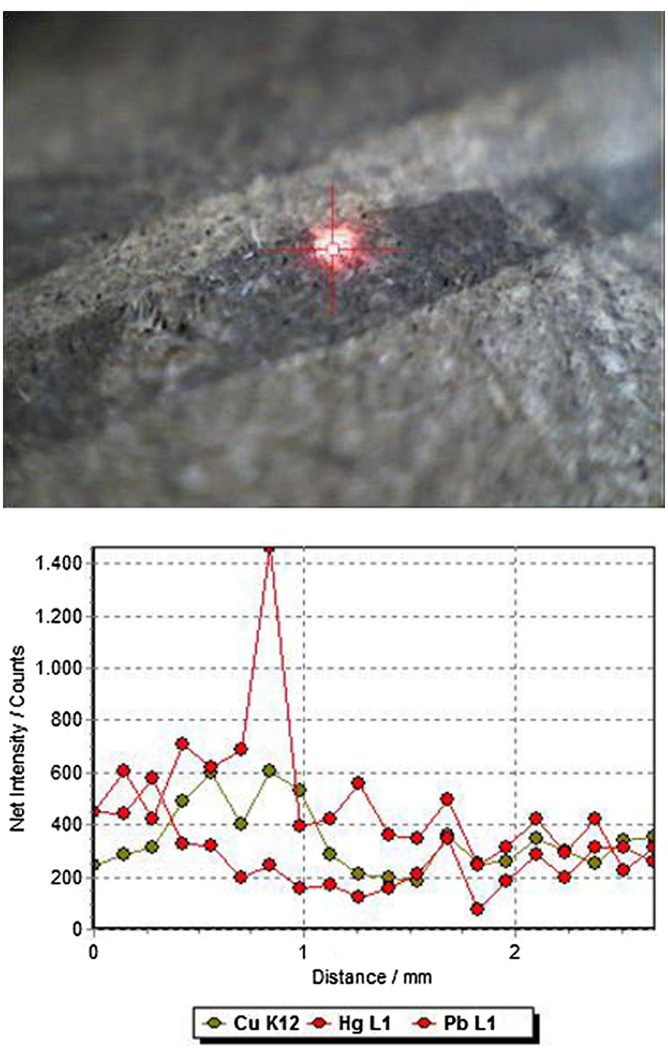

Fig. 39. IOL Tib J 1361, XRF-analysis, magnification 20×. Brown carbon ink. Line scan with traces of Pb and Cu. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 40. IOL Tib J 1363, photographed under normal light and on a light box.

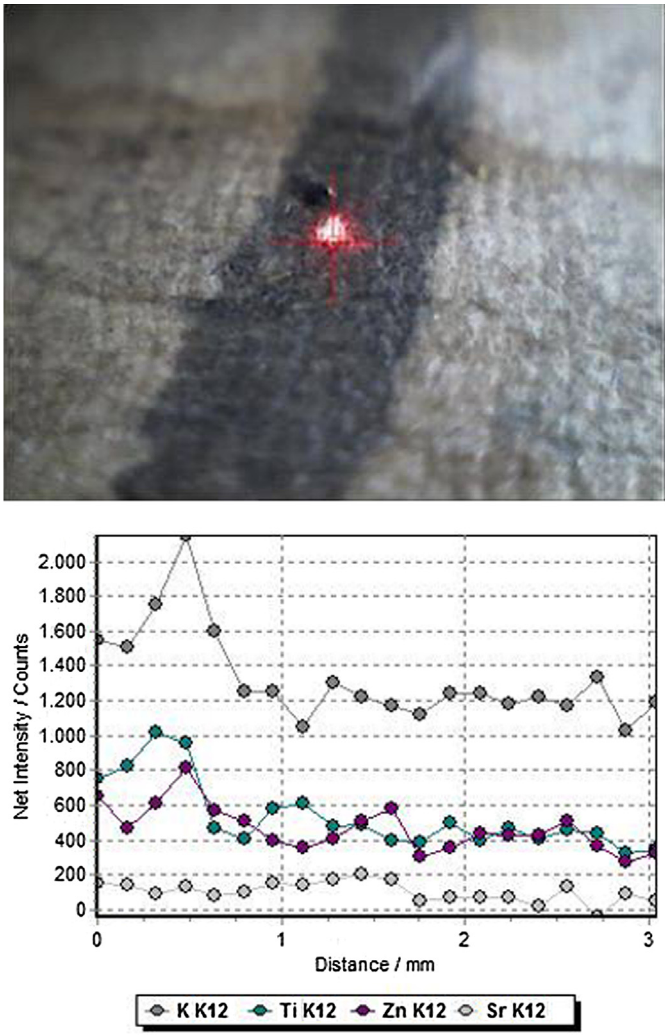

Fig. 41. IOL Tib J 1363, XRF-analysis, magnification 20×. Black carbon ink. Line scan with Fe and traces of K, Ti, Zn.

Table 2
Elemental composition of ink and paint on the Tibetan manuscripts and artefacts.

Black ink	
C	IOL Tib J 1363, 1365 (Cu)
C (Cu)	IOL Tib J 709, 1364, 1366
C (Fe)	IOL Tib J 1363
C (Fe–Cu)	IOL Tib J 308, 709, 1366
C (Fe–Zn/As)	IOL Tib J 308 (As–Zn), 1362 (Zn), 1363 (Zn)
C (Pb–Hg)	IOL Tib J 1366, 1365
Red ink	
Fe	IOL Tib J 1362, 1365
Fe–Pb	IOL Tib J 1362 (Cu), 1366, 1365
Pb	IOL Tib J 1410
Pb–Hg	IOL Tib J 1362, 1365, 1410 (Fe, Cu, As)
Rose	
Pb–Hg	IOL Tib J 1366 (As, Cu, Zn)
Orange	
Pb–Hg	Tib 1365 (Cu–Zn)
Brown	
Pb	IOL Tib J 709
Pb–Hg	IOL Tib J 1361, 1362 (Cu), 1365, 1410 (Cu, As)
Fe–Pb	IOL Tib J 308 (Zn), 709, 1366, 1365
As– Fe	IOL Tib J 1410 (Hg)
Yellow	
As	IOL Tib J 1366 (Hg), 1410 (Fe, Hg, Zn)
Green	
Ca–Cu	IOL Tib J 1366, 1365, 1410 (Pb)
Cu–Cl	IOL Tib J 1362 (Zn), 1364, 1365
Cu–Fe	IOL Tib J 1365, 1410
Cu–Pb	IOL Tib J 1364, 1366
Cu–Fe–Pb	IOL Tib J 1364 (Zn), 1410
Blue	
Fe–Ca–K	IOL Tib J 1364
Ca–Zn–S–Cl	IOL Tib J 1410
Stamps:	
Red: Hg–Zn–Pb	IOL Tib J 1126, Or.15000/512
Brown: Pb–Hg–Cu	Or.15000/513
Lines:	
Red: Pb–Fe–Hg	IOL Tib J 1366 (same ink as used for rose)
Brown: Fe–K–S	IOL Tib J 709, 1410 (As)
Black: C (Cu)	IOL Tib J 1365
Paper	
Fe–Ca–K–Cu–Mn–Si	IOL Tib J 1126, Or.15000/512
K–Ca–Mn–**Cl**	IOL Tib J 308, 1364
Ca–Fe–K–Mn–**Zn**	IOL Tib J 709
Zn + Cl	IOL Tib J 1361, 1366, 1365, Or15000/513

Table 3
Raw material and techniques used for paper making of the Tibetan manuscripts.

Ramie and hemp (Rag paper): IOL Tib J 308, IOL Tib J 1410 vol. 72, IOL Tib J 1126, Or 15000/512, IOL Tib J 1366, IOL Tib J 1364, IOL Tib J 1362, IOL Tib J 1365, IOL Tib J 1361.
Various components mixed, including Daphne or Edgeworthia sp. and unidentified fibres: Or 15000/513, IOL Tib J 1363.
Wove: IOL Tib J 1410, Or 15000/513.
Laid regular: IOL Tib J 308.
Laid irregular: IOL Tib J 709, IOL Tib J 1126, Or 15000/512, IOL Tib J 1366, IOL Tib J 1362, IOL Tib J 1365, IOL Tib J 1361, IOL Tib J 1363.
Laid patchy: IOL Tib J 709, Or 15000/512.

Table 1
Colours used for painting the Tibetan manuscripts and artefacts.

Manuscript	Yellow	Brown	Black	Red	Blue	Green	Form
IOL Tib J 308		Blood?	C(Cu)				Book (pothi)
IOL Tib J 709		Brown lead	C(Cu)				Book (pothi)
IOL Tib J 1126				Cinnabar (Zn–Pb)			Letter with seal
IOL Tib J 1361		Brown lead (Cu)					Stencil
IOL Tib J 1363			C(Fe–K–Ti–Zn)				Drawing
IOL Tib J 1364		Brown lead (Hg)	C(Cu–Hg)		Indigo	Atacamite	Ritual item
IOL Tib J 1410	Orpiment (Hg)	Pb–Hg	C(Pb–Hg)		Indigo	Cu	Book (pothi)
IOL Tib J 1366	Orpiment	Brown lead (Fe–Hg) Brown lead (As–Hg)	C(Cu)	Ochre (Pb) (dark)		 Atacamite (Pb–Zn)	Hung painting
IOL Tib J 1362		Brown lead-Fe(Hg–Cu)	C(Fe–Zn)	Ochre (Pb) (dark) Ochre (Cu) (light) Red lead (Hg) (orange)		Atacamite (Zn)	Banner
IOL Tib J 1365	ochre (Hg)	Brown lead (Hg)	C(Cu)	Ochre (Pb) Red lead (orange)		Atacamite (Zn)	Banner
Or.15000/512				Cinnabar (Zn–Pb)			Letter with seal
Or.15000/513		Brown lead (Hg–Cu)					Letter with seal

Table 4
Features of paper in Tibetan manuscripts and art objects from Dunhuang.

Pressmark, sample location	Form	Fibre composition					Type of paper						No.of layers	Texture	Thickness (mm)	Fibre distribution
		Ramie	Hemp	Paper mulberry	*Daphne/ Edgeworthia sp.*	Other	Wove	Laid								
								Laid lines within 3 cm	Chain lines (cm)	Regular	Irregular (wavy)	Patchy				
IOL Tib J 153 f.1 Right upper corner		+ Long Fibrillated	+ Long Fibrillated					16		+			2		0.18–0.24	Even
IOL Tib J 221 f.2 7.5 cm on the upper edge from the left upper corner on verso side		+	+					20		+			2		0.19–0.2	Even
IOL Tib J 300 f.3 Right bottom corner		+ Short Damaged Rigid	+ Short Damaged Rigid			Flax		14–16	5.5–7–6		+	+	1		0.12–0.16	Uneven
IOL Tib J 308 f.4–6 f. 4 right bottom corner	(possibly the same type of paper as folio 1)	+	+ Long Well preserved					16		+			2		0.22–0.34	Uneven
IOL Tib J 444 f. 7-106 f.10 right bottom corner			+					14–15	Occasionally visible: 6-6-5.5-3.5-3.5-5.5-6		+		1		0.1–0.2	Uneven
IOL Tib J 709 vol. 14 ff. 42–79 Left upper corner of folio 3 (44)				+ Long, good quality		Silk?		21			+	+	2–3	Smooth, polished	f.44: 0.23–0.3 f.46: 0.13–0.20	Uneven
IOL Tib J 1126 vol. 55: 55 Right bottom corner	Folded document, letter from Dunhuang, 20–23 × 30.5–31 cm with a square vermillion seal at the bottom right 6 × 6	+						12–15			+		1	Rough		Uneven
IOL Tib J 1361 Right upper corner	Drawing, stencil	+	+					11–12			+		1	Rough	0.23–0.31	Uneven
IOL Tib J 1362 4.5 cm on right side from the bottom	Photo documentation of painting done	+?	+ Long fibres					11			+		1	Rough	Thick Not measured because of mounting	Uneven
IOL Tib J 1363 Left of the bottom corner area	Drawing, stencil					? Fibres not identified		12			+		1	Rough	0.24–0.26	Uneven
IOL Tib J 1364 Upper part, recto side	Fan	+ Short deteriorated	+ Short deteriorated			?	Not visible	Not visible	Not visible	Not visible	Not visible	Not visible	Many layers	Rough		Not visible

IOL Tib J 1366 7 cm from the right bottom corner on the right side edge	45.5 × 30.5 cm in two panels of the same type joined together: 24.5 × 30.5 cm and 22 × 30.5 cm	+ Short fibres, highly damaged, rigid	+ Short fibres, highly damaged, rigid					12–13	7.5–8.2 – 8.8	+		1	Rough	0.2–0.36	
IOL Tib J 1367 9 cm from the bottom on right side edge		+ Long fibres, highly fibrillated	+ Long fibres, highly fibrillated			Cotton		12		+		1	Rough	Thick Not measured because of mounting	Uneven
IOL Tib J 1410 vol. 72 f. 88 Left side: 7.7 cm from the left upper corner on the upper edge Right side: right upper edge (upper corner area)	2 types of paper Two types of woven paper within this one folio stuck together; 26.5 × 37.8 cm on the left side and 31 × 26.5 cm on the right side:	1)+ Long	1)+ Long	2) + Short Rigid		1) Flax ? 2) Silk	+					2	1) Soft paper made of shorter fibres 2) Rough, made of longer fibres, Textile sieve print	1) 0.21–0.29 2) 0.26–0.33	1) Even 2) Uneven
IOL Tib J 1411 vol. 72 f.89 Sampled left bottom corner area (close to dark ink drawing fragment)				+ Long, good quality			+					1	Rough	0.1–0.19	Uneven
Or 15000/512 2 cm on upper edge from the right upper corner		+	+					12		+	+	1	Rough	0.11–0.14	Uneven
Or 15000/513 2 cm from right edge on the bottom edge			+?	+	+	?	+					2	Rough	0.19–0.21	Uneven

Asia that were analysed (IOL Tib J 1126 and Or.15000/512) the pigment used for stamping with a seal was cinnabar. By contrast in the letter from Tibet, red lead was used for the seal.

The hung painting IOL Tib J 1366 was made from local Dunhuang paper. On the other hand, these pigments were not exclusively produced in the Dunhuang area, and do not provide evidence, one way or the other, of local production. A hint of the process of painting is given by the hues made out of mixed components. Traces of characteristic elements suggest the painter's repeated use of the same brush for different colours. Though the banner fragments investigated (IOL Tib J 1362 and 1365) are prepared out of different paper, they share the component of long ramie fibres, which create a strong support. The pigments used for colouration in these two banners are nearly the same, and comparable stylistic elements are painted with the same kind of ink, suggesting that these banners derived from one workshop or local tradition. Concerning the painting technique, here our analysis shows that the painters generally took one brush for green and black and another for the brown to red colours.

Another question posed at the beginning of this research was whether it would be possible to show any correlation between materials chosen and the intended function of the objects. This was most evident in the choices made in the selection and construction of paper. For example, most of the layered paper with a polished surface made of long and well preserved raw material is found in manuscripts. The ritual item IOL Tib J 1364 was constructed with many layers of paper to give it the necessary stability when held upright.

Both the stencil and the sketch in our sample (IOL Tib J 1361 and 1363) were executed on very similar type of thick, absorbent laid irregular paper, with uneven fibre distribution and a rough surface. It is possible that this kind of strong paper was preferred for stencils and sketches intended to be used repeatedly to transfer patterns on other supports. In fact most papers in our sample were laid irregular papers in a similar pattern to that found in paper of Chinese manuscripts from Dunhuang. Wove paper was found in letter IOL Tib J 1410 from Central Tibet, which is also distinguished from the locally-produced paper by its fibre composition. On the other hand, analyses of the brown to black lines of the stencil and the sketch show that they were drawn with inks of completely different compositions.

Our collaborative work resulted in collection of data that will provide a solid reference for future work on objects from Central Asia. The techniques used to create ink and paper for different kinds object revealed by this study may include features specific to this region, and may also reflect communication and exchange between much wider areas of Central Asia, Tibet and China. Future research on objects from other Central Asian archaeological sites, such as Turfan and Khotan, will allow us to further contextualize the results here, and better understand the dynamics of manuscript and painting technologies across the region.

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